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# A descriptive analysis of the upper body kinematics of conductors

Jessica Rosemary Flammia
*University of Windsor*

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By

**Jessica R. Flammia**

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by

**Jessica R. Flammia**

APPROVED BY:

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B. Kotowich
School of Creative Arts

---

S. Scharoun Benson
Department of Kinesiology

---

N. Azar, Co-Advisor
Department of Kinesiology

---

D. Andrews, Co-Advisor
Department of Kinesiology

December 13, 2023

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ABSTRACT

A high prevalence of the physical symptoms of musculoskeletal disorders has been identified in conductors (Luger and Trouli, 2023; Geraldo and Fiorini, 2022). Both repetition and non-neutral postures have been identified as risk factors in the development of musculoskeletal disorders (Kumar, 2008; Frievalds, 2018) and are clearly present in a conductor's job description. The current study aims to examine conductors' exposures to these factors by answering the guiding research question: what does the upper body movement patterns of a conductor look like? Seven conductors were instrumented with the Xsens MVN Awinda™ motion capture system during one of their ensembles' regular rehearsals and data were collected while the participants conducted their ensemble. Data were reprocessed using the Xsens software's built-in biomechanical model and exported to Excel where outcome variables (including mean, median, maximum, and minimum joint angles, the joint range of motion, and the intra-subject variability, for all available rotations of the upper limb joints and the trunk and neck segments) were analyzed. Percent time spent in neutral and non-neutral postures (McAtamney and Corlett, 1993; Humadi et al., 2021) was also calculated. The inherent repetition was clearly visible in time series graphs and large ranges of motion were present at all upper limb joints (i.e. shoulder flexion R:165.5°, L: 160.2° and elbow flexion R:174.2°, L:187.2°). Notable amounts of time were spent in non-neutral postures, especially on the right side (i.e. shoulder flexion 81.7%, wrist extension 73.5%). Future directions include increasing the sample size and standardizing music conducted to improve generalizability.

# DEDICATION

To my music teachers and mentors – thank you for igniting my passion, instigating my curiosity, and teaching me the importance and value of hard work, daily practice, and dedication.  The time and effort you put into developing and nurturing my skills in the arts have benefitted me far outside the classroom, more than you could ever know.

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To the Human Kinetics faculty and staff – my warmest thanks for your support and guidance throughout my time at the university. I have learned so much from each of you.

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LIST OF ABBREVIATIONS

| | |
|---|---|
| ABD | Abduction |
| ADD | Adduction |
| AR | Axial Rotation |
| E | Extension |
| ER | External Rotation |
| F | Flexion |
| IMU | Inertial Measurement Unit |
| IR | Internal Rotation |
| ISV | Intra-Subject Variability |
| L | Left |
| LLB | Left Lateral Bending |
| MAX | Maximum |
| MIN | Minimum |
| P | Pronation |
| PI | Primary Investigator |
| R | Right |
| RD | Radial Deviation |
| RLB | Right Lateral Bending |
| RMSE | Root Mean Square Error |
| ROM | Range Of Motion |
| RULA | Rapid Upper Limb Assessment |
| S | Supination |
| UD | Ulnar Deviation |
| WMSD | Work-related Musculoskeletal Disorder |

GLOSSARY

| Term | Definition |
|---|---|
| Abduction | Movement away from the midline of the body (Tortora and Nielsen, 2014) |
| Adduction | Movement towards the midline of the body (Tortora and Nielsen, 2014) |
| Axial Rotation | Rotation around a vertical axis (McGinnis, 2013) |
| Bar or Measure | Both words used interchangeably to describe a unit of musical time made up of a pre-specified number of beats. May be labelled numerically for easy reference (Burkholder, 2014) |
| Baton | A tool, generally thin and generally wooden, that is used as an extension of the conductor's upper limb to aid in conducting a musical ensemble (Jones, 1948) |
| Beat | The smallest measurement of a musical unit of time (Burkholder, 2014) |
| Choir | A group of musicians who sing together. A choir usually has a choral conductor, and may or may not have musicians who sing in different vocal ranges (Burkholder, 2014) |
| Composer | The author of a piece of music (Burkholder, 2014) |
| Composition | The process of creating a piece of music, or a piece of music (Burkholder, 2014) |
| Conducting | The process of leading an ensemble of musicians, generally through large gestures (Jones, 1948) |
| Conductor | A person responsible for leading an ensemble of musicians, generally providing instruction and leadership in the form of large gestures (Burkholder, 2014) |

| | |
|---|---|
| Ensemble | A group of musicians who practice and perform together (Burkholder, 2014) |
| Extension | An increase in angle between two bones (for example extending the elbow) (Tortora and Nielsen, 2014) |
| External Rotation | Shoulder movement that occurs around the longitudinal axis in the transverse plane in which the palm of the hand turns away from the body if starting from anatomical position (McGinnis, 2013) |
| Flexion | A decrease in angle between two bones (for example bending or flexing the elbow) (Tortora and Nielsen, 2014) |
| Force | An action that causes bodies to be pushed or pulled in different directions (Frievalds, 2018) |
| Ictus | Imaginary line that represents the transformation point between first and subsequent beats (Jones, 2009) |
| Internal Rotation | Shoulder movement that occurs around the longitudinal axis in the transverse plane in which the palm of the hand turns towards the body (McGinnis, 2013) |
| Intra-Subject Variability | The difference found within one subject in multiple measurements of one joint or segment angle |
| Lateral Bending | Sideways bending of the trunk or neck (Tortora and Nielsen, 2014) |
| Maximum | Point in a dataset with the greatest value |
| Meter | Repeating patterns of strong and weak beats found within a piece of music (Burkholder, 2014) |
| Minimum | Point in a dataset with the lowest value |
| Muscle Memory | A non-scientific term used to describe an internal kinesthetic memory musicians and conductors have that allows them to perform repetitive movement patterns easily without conscious thought (Jordan, 2009) |
| Phrase | A musical sentence with a distinct beginning and ending (Burkholder, 2014) |

| | |
|---|---|
| Posture | The position held by the human body (Jaffar et al., 2011) |
| Pronation | A movement of the forearm in which the palm of the hand is turned away from the body (in anatomical position) (Tortora and Nielsen, 2014) |
| Radial Deviation | Wrist movement that occurs when the hand moves towards the forearm in the direction of the thumb (McGinnis, 2013) |
| Range of Motion | The difference between the maximum and minimum joint angles; the full extent to which a joint or segment is able to move in a given direction |
| Repetition | The act of completing the same movement or motion multiple times within a specific time frame (Gallagher and Heberger, 2013) |
| Rhythm | A pattern of notes of short and long duration found within a piece of music. Unlike the meter, the rhythm may not repeat throughout the entire composition (Burkholder, 2014) |
| Supination | A movement of the forearm in which the palm of the hand is turned towards the body (in anatomical position) (Tortora and Nielsen, 2014) |
| Timbre | The identifiable characteristics or sound of a specific instrument or group of instruments (Burkholder, 2014) |
| Time signature | A sign placed at the beginning of each piece or section of music that denotes the numerical relationship of the number of beats in a bar (Burkholder, 2014) |
| Ulnar Deviation | Wrist movement that occurs when the hand moves towards the forearm in the direction of the little finger (McGinnis, 2013) |
| Upper Limb | Anatomical term representing the arm, forearm, and hand |
| Vinculum | The line separating the numerator and denominator in a mathematical fraction |


Figure 1.  A graphical representation of some common terms used in this proposal. (Hill and Hill, 1893)

| | |
|---|---|
| A | Time Signature |
| Blue Parentheses | One Bar or Measure of Music |
| B | One Beat of Music |
| Purple Arrow | One Phrase of music |

# CHAPTER 1

# INTRODUCTION

Conductors are an integral member of any musical ensemble. They act as the leader of the group, moving their upper limbs in specific patterns to non-verbally communicate expectations about tempo, dynamics, and emotion. They gesture to provide cues to ensure musicians perform as one unit, and use their experience and skill to act as an advocate to ensure the goals of the piece of music are met.

Although conductors often add their own flair and style, the gestures they use as a non-verbal communication tool and patterns they present follow standard outlines (Jones, 1948; McElheran, 1966). Using nearly all joints of the upper limbs, conductors generally conduct with their right hand (even if they are left-handed) and use their left hand for supplementary cues or to add emphasis (Jones, 1948). They may choose to use a baton as an extension of their upper limb, or to simply conduct with their hands.

Conductors work with a variety of different styles and sizes of ensembles. For some individuals, conducting is a full-time job. It is very challenging to quantify the number of conductors currently working or volunteering their time in Canada but analyzing the numbers in some key groups can provide an idea of just how many people spend some of their time conducting on a regular basis. In 2017, a National Choral Census commissioned by Choral Canada identified approximately 28,000 choirs throughout Canada (Hill, 2017). There are approximately 14,600 elementary and secondary schools in Canada (Council of Ministers of Education Canada, 2021) with about 75 % of which having at least one dedicated music teacher (Hill Strategies Research, 2010). There were also approximately 140 orchestras enrolled with

Orchestras Canada in the 2018-19 season (Orchestras Canada, 2019) and each would have had its own conductor. Although there is likely some overlap between these numbers (for example, a high school music teacher conducting a community choir on the weekends), these values do not represent all the different types of conductors that might be present in each community.

The rates and patterns of work-related musculoskeletal disorders (WMSD) in conductors is not a topic that has been extensively researched. A WMSD is an injury to the musculoskeletal system that occurs due to risk factors associated with occupational tasks. There are four main categories of risk factors for WMSDs: psychological, individual, physical (Kumar, 2008), and environmental (Whiting and Zernicke, 2008). There are a wide range of risk factors that can be sorted into one of these categories. All are important, but this study will focus on quantitatively describing the upper body motions involved in conducting to make research-based conclusions about the physical risk factors associated with the activity.

Physical risk factors can be further categorized into risk factors associated with force, repetition, and posture (Potvin, 2014). Force is defined as an action that causes bodies to be pushed or pulled in different directions (Frievalds, 2018). As the magnitude of an applied force increases, the risk and severity of a resulting injury also increases (Adamec et al., 2013; Bates et al., 2013; Bernard et al., 1997; da Costa and Vieira, 2010; Skotte and Fallentin, 2008). Conducting, as with performance on some other musical instruments, does not involve any substantial lifting or the application of external forces, but the cumulative effects of the inertial forces during a conductor's upper limb movement patterns could be significant over time. Repetition is defined as the act of completing the same movement or motion multiple times within a specific time frame (Gallagher and Heberger, 2013) and is closely related to other risk factors. Repetition is a significant risk factor in the workplace (Frevialds, 2018; Gallagher and

Heberger, 2013) and the musical performance sector is no exception (Beckett et al., 2015; Flammia and Azar, 2021; Hopper et al., 2017; Shan and Visentin, 2003). Although not thoroughly investigated in conductors, repetition is clearly a part of a conductor's job description as their conducting patterns must be repeated from the start to finish of each musical piece. Posture is a term used to refer to the position of the body (Jaffar et al., 2011). Non-neutral postures, especially when held over time, place an increased stress on the involved tissues and increase the risk of an injury (Kumar, 2008). Non-neutral posture has been identified as a strong risk factor in the development of injuries in the shoulder and hand/wrist (Bernard et al., 1997; da Costa and Vieira, 2010; Jaffar et al., 2011) and has also been connected to injuries in instrumental musicians (Coker et al., 2004; Pappa et al., 2020). When analyzing WMSD risk factors for any job, force, repetition, and posture are not the only possible risk factors, but they are the primary physical risk factors. Consequently, it is important to analyze how they work together to increase the chance of developing a musculoskeletal disorder in the workplace.

Neither the kinematics of conducting of any style nor the rates and patterns of WMSDs in conductors has been substantially studied, but the importance of this future research area can be highlighted by analyzing the results of similar studies in jobs or tasks with comparable physical demands. Conducting involves the movement of the upper body under light-to-no external load in front of the conductor with repeated motions completed over a long period of time. Although seated, performers on other musical instruments such as the piano and drum set complete a substantial amount of upper limb movement in front of the body, in ways that may be comparable to a conductor. When reviewing kinematic data collected from pianists, repetition was highlighted as one of the primary injury risk factors (Monino et al., 2017). The amount of repetition and time spent in non-neutral postures by percussionists who specialize on the drum set were also highlighted in a separate kinematic overview (Flammia and Azar, 2021). Certain aspects of work done by grocery store cashiers and light manufacturing work done in a factory setting can also be loosely compared to the work completed by a conductor. The results of a cashier's frequent reaching and grasping were moderated by having a workstation that was adjustable in height, and education on appropriate grocery-packing biomechanics. These moderations resulted in decreased discomfort and WMSDs experienced by grocery store cashiers (Lang et al., 2018). Kinematic analysis of light factory work (work that requires minimal lifting, reaching, and moving such as working on a line attaching a plastic piece to a product) also identified repetition as an important risk factor in the development of musculoskeletal complaints, especially in individuals completing cyclic tasks (Schall et al., 2021). Although playing the piano or drum set, packing groceries, and completing light manufacturing work are not quite the same as conducting a musical ensemble, their similarity to the movement patterns required and the findings of kinematic analyses on these activities highlights the importance of quantitatively analyzing the kinematics of conducting.

The tools used in kinematic analysis allow researchers to collect the data necessary to quantify and analyze the associated movement patterns. With the number of different styles and makes of tools available, choosing one that allows the data collection to occur in an environment that is as close to the natural environment of a conductor as possible is key. Motion capture systems can produce a wide range of valuable information (Robertson et al., 2014) and come in several different styles. The "gold standard" systems rely heavily on cameras to track the positions of active light-emitting markers or passive reflective markers (Robertson et al., 2014). Due to the requirement for multiple cameras, these systems are not ideal for situations in which other objects (such as music stands or musicians) might be blocking the cameras' lines of sight of the markers (Topley and Richards, 2020). These systems are also time consuming to set up (Perrott et al., 2017) and are not mobile (Bolink et al., 2016; Winter, 2005). Inertial measurement unit (IMU)-based systems, such as the Xsens MVN Awinda™, are an ideal motion capture tool that addresses some of the restrictions present with gold-standard, laboratory-based motion capture systems. The MVN Awinda™ system features 17 wireless IMUs with an adjustable strap-based setup (Schepers et al., 2018). It is ideal because it is portable and the hardware has been shown to be both reliable and valid in collecting kinematic data outside a laboratory setting (Cutti et al., 2008; Khurelbaatar et al., 2015; Robert-Lachaine et al., 2017). When compared to a comparable gold standard system, the associated software and the built-in biomechanical models of the Xsens™ MVN Analyze system presented a significant difference in root-mean-square error (RMSE) of 21.6° between the values for the upper limbs (Mavor et al., 2020). The potential shortcomings of the Xsens™ biomechanical model are important to acknowledge because the movement patterns executed by conductors rely heavily on their upper limbs. However, Xsens™ developers made improvements to the biomechanical models used specifically for the upper limbs since Mavor et al (2020) collected their data (L. Abraha, personal communication, August 16, 2021). Furthermore, Xsens™ systems have been valuably and extensively used in recent sport science research to collect data in athletes' regular performance settings where data collection with other systems would have been difficult, cumbersome, and in some cases, impossible (e.g., Blair et al., 2020; Klitgaard et al., 2021; Pedro et al., 2021; Setuain et al., 2017). Considering the lack of research currently available on the kinematics of conducting, the benefits of being able to collect these data outside of a laboratory setting outweigh the potential limitations.

Comparing data collected on conductors to assessment tools that are well-known in the biomechanics and ergonomics field will allow researchers unfamiliar with the job description and physical demands of a conductor to understand the extensiveness of postures associated with this job. The rapid upper limb assessment (RULA) is an ideal tool for assessing posture because it characterizes observed postures into posture bins (i.e., ranges of joint angles) developed based on pre-defined risk factors (McAtamney and Corlett, 1993). Although it is not a tool developed for use specifically with conductors or other musicians, the analysis of conductors' movement patterns within the lens of RULA posture bins using the data collected with the Xsens™ system will identify the level of necessity of future research in this area.

### *1.1 Statement of Purpose and Research Questions*

The purpose of this study was to create a quantitative kinematic description of a conductors' trunk, neck, and upper limb postures while conducting in their standard practice or performance environment. Using RULA as a tool to compare the postures of conducting (quantitatively described using the Xsens™) to pre-determined posture bins, this task can be assessed in ways similar to more standard and extensively researched jobs (such as in manufacturing). The results of this study provide a framework on which future studies in this research area can be built. They also provide a starting point allowing healthcare and music professionals to make research-based recommendations on warm-up, cool-down, and teaching strategies to reduce conductors' risk of developing work-related musculoskeletal disorders.

The research question guiding this study was, what do the upper body movement patterns of a conductor look like? Specifically:

i. Would conductors' overall movement patterns be identified as neutral or non-neutral based on RULA posture bins?

ii. Which joint(s) in conductors' upper bodies produce(s) the most dynamic range of motion?

# CHAPTER 2

# LITERATURE REVIEW

## *2.1 What is a Conductor?*

When any group of musicians perform together in an ensemble (i.e., group; Burkholder et al., 2014), a high level of synchronicity substantially improves the quality of the sound produced by the group. For this to happen effectively, there must be one designated leader in charge. Comparable to the human body, where the brain controls most of the movement, a conductor provides the leadership and control in a musical ensemble. They are not only responsible for ensuring synchronicity between the musicians that make up the ensemble, but they are also responsible for communicating the expected rhythmic characteristics of the piece of music being performed and the "colour" of the sound (Jordan, 2009). When they present themselves and their conducting movements with clarity and confidence, they will be rewarded with clarity in execution from their musical ensemble (Jones, 1948).

Conductors work together with their ensembles, (i.e., a group of singers or other musicians), to perform songs or musical compositions (i.e., pieces of music, Burkholder et al., 2014). To the untrained eye, a conductor may simply look like a person waving their upper limbs around during a musical performance, but the conductor's upper limb movement patterns are a heavily studied part of their craft that are used to effectively communicate subtle differences to their musicians without saying a word (Flash and Berthoz, 2021; Jordan, 2009). This non-verbal form of communication ensures the ensemble produces the exact sound expected by the conductor and the composer (i.e., the author, Burkholder et al., 2014) of the piece of music being performed. Conducting is *not just* gesturing. It involves communicating without using words, presenting confidence and leadership, effectively expressing creativity, trusting one's own musical aptitudes, and advocating for the composer's goals and ideas for the piece of music (Jordan, 2009).

### 2.1.1 Conducting Gestures

Written music is like its own language and is transcribed in a structured pattern. This structured pattern, combined with Italian terms and symbols, ensures that any musician who can read music can reproduce the sounds intended by the composer. Music notation is divided into even units of time called beats, and these beats are combined into small groups called bars. These beats and bars are combined to form phrases or musical sentences with a strong start (like a capital letter in a written sentence) and rewarding ending (like punctuation). These bars of music follow patterns of strong and weak beats, and most often include combinations of 2, 3, or 4 beats (Burkholder et al., 2014). The beat patterns are described as the *meter* of the music and have labels at the beginning of each section of written music called *time signatures* (Burkholder et al., 2014). Conductors follow conducting patterns, or upper limb movement patterns, that vary depending on the number of beats per bar in the composition they are conducting. They receive this information by looking at the time signature at the beginning of their music. Although conductors have the freedom to put their own flair into their conducting patterns, most follow standard beat outlines (Jones, 1948; McElheran, 1966). More complicated beat outlines are developed as variations of the simple beat outlines and are used as necessary in compositions with more complicated beat patterns (Jones, 1948). These adaptations are made to adjust for specific rhythmic figures found in the various compositions performed by the ensemble (Jones, 1948). These beat outlines become second nature to experienced conductors. They can perform the required movement patterns without a conscious thought, making it easier for them to switch quickly, gracefully, and flexibly between meters while focusing on the music and the musicians.

This “muscle memory” can also present a challenge that conductors need to overcome: poor movement habits engrained while learning musical scores or while in rehearsal will naturally be used during performance as well (Jordan, 2009).

A solid movement pattern starts at the shoulder and follows through effortlessly to the elbow, wrists, and fingers with each joint playing an important role. The wrist carries most of the motion, so it requires the most flexibility (Jones, 1948; Moe 1968). The size of the gesture conducting the beat is generally proportionate to the level of sound expected from the musical ensemble, but numerous other gestures or facial expressions can be used to convey these pieces of information as well (Jones, 1948; Linton, 1982). Generally, conductors conduct with their right hand even if they are left-handed because musicians are trained to follow right-handed conductors and it can be challenging to switch (Jones, 1948). The left hand remains engaged by providing other cues to certain sections of the ensemble or emphasis to the actions of the right hand (Jordan, 2009; McElheran 1966). These movements mostly occur between eye and mid-trunk level with the upper limbs out in front of the conductor’s body (Jordan, 2009; McElheran 1966).

Conductors may choose to conduct simply with their hands, or by holding a baton (a thin stick of varying lengths, usually wooden and light in colour, that can act as an extension of the conductor’s upper limb). An experienced conductor should be able to communicate clearly with both (Jones, 1948). Conductors leading instrumental music groups are more likely to use the baton due to the more rhythmically complex nature of instrumental music (the tip of the baton provides a more precise instrument compared to the human hand) and the potential for a larger distance between the musicians and the conductor (Jones, 1948; Moe 1968). Choral conductors (i.e., conductors who specifically work with a group of singers, or a choir) use the baton less frequently because their musicians are usually closer together, and they can benefit more from the increased variability in shapes that can be formed with the hand (Jones, 1948). It is important to note that the decision to use a baton is often left up to the conductor and the way in which they were taught, but choral conductors who simultaneously conduct a choir and instrumental ensemble have a more diverse group of musicians to consider when making their decision.

Each movement and change in direction in a conducting pattern represent a new beat. It is important that each beat is clear and easily differentiated from the beats before and after it (Jones, 1948; Linton 1982). The first beat of each bar is generally considered the most important beat and is the strongest in emphasis when compared to the others. It is always presented by a strong downward beat that accelerates towards the ictus, or imaginary line that acts as the transformation point between the first and subsequent beats (Jordan, 2009). Although the number of beats in each bar, the tempo, or the rhythmic characteristics of the music, might change throughout the composition, the ictus will remain in the same location, making it a unique marker for future movement analysis.

Compared to instrumental conducting, in choral conducting it is very common to simplify more complex meters into their lowest common value for ease of movement (Jones, 1948). The time signatures used to label meters in written music can be compared to basic fractions, like what is taught in the elementary mathematics curriculum. For example, a time signature of 4/8 represents a musical meter that includes four eighth notes per bar (NOTE: the vinculum, or line separating the numerator and denominator in a mathematical fraction, is not used in a time signature. See Fig. 1, p. xii). When conducting a basic four-pattern, the conductor would move in a downward motion for the first beat, then left on the second, right on the third, and back up to the starting position on the fourth. This can also be simplified for ease of movement and conducted like a time signature of 2/4 (with two quarter notes per bar, where one quarter note is equivalent to two eighth notes). This would require less upper limb movement from the conductor with their upper limb only moving down, then back up for each bar of music. It has also been found that less upper limb movement from the conductor produces smoother word flow and better phrasing from the choir (Jones, 1948). The very rapid tempo seen in instrumental music that makes conducting each beat particularly challenging is very rare in choral music (Jones, 1948). Also, sometimes when you are working with a composition in a very slow tempo, using a more complex beat outline will be more desirable to ensure rhythmic precision (Jones, 1948).

One of the most important skills for a conductor to possess is a strong internal sense of rhythm (Jordan, 2009). It is a challenging concept to teach. It is not something that can be learned only through reading or music theory, as kinesthetic feeling will also play a large role (Jordan, 2009). This deep understanding of rhythm and ability to "feel the groove" of the music will play an integral role in effective non-verbal communication between a conductor and their ensemble (Jordan, 2009).

When learning and forming a bond with their music, conductors are at a disadvantage compared to instrumental musicians. Instrumental musicians have a deep and intimate awareness of their hands because their hands are used to connect with their instrument, which connects them directly with the sound they produce (Jordan, 2009). Conductors still rely heavily on the work of their hands, but they do not have the same level of intimate awareness because they do not have that same opportunity for tactile connection with the sound that they produce (Jordan, 2009). Without this tactile perception, it is hard for them to really feel their hands forming and shaping the sound produced by the musical ensemble they are conducting (Jordan, 2009).

Conductors have a lot to think about when they are leading their ensemble in performance. As mentioned previously, a smooth and graceful conducting pattern is more likely to produce a smooth and graceful phrasing from the ensemble (Jones, 1948; Flash and Berthoz, 2021), but in performance there is the audience to take into consideration as well. What the audience hears will be affected by what they see, so a smooth, graceful conducting pattern will augment a smooth, graceful performance (Jones, 1948); this is just one more thing that the conductor will have to consider when creating their conducting patterns. Although this study will focus specifically on the physical aspects of conducting, there is so much more involved!

### 2.1.2 Conducting as an Occupation

For some individuals, conducting is a full-time job. There is a substantial amount of conducting training offered at the graduate and doctoral level, where conductors can specialize in the conducting of a specific group of musicians. In the community, conductors work with a variety of different ensembles such as choirs, professional orchestras, wind ensembles, marching bands, community bands, youth ensembles, or student ensembles in schools. It is challenging to specifically quantify the number of conductors in any one area, but a National Choral Census commissioned by Choral Canada, the national voice of the Canadian Choral community, estimated that in 2017 there were 3.5 million Canadians singing in approximately 28,000 choirs throughout Canada (Hill, 2017). These choirs ranged in members' age from youth to senior and represent both amateur and professional choirs. Although some conductors may conduct more than one choir, and not each of the choirs in Canada has a conductor with a doctoral degree or comparable professional training, each choir would have someone in the choral conductor role.

Outside of choirs, conductors also work with other musical groups such as orchestras, wind ensembles, marching bands, community bands, youth ensembles, and student ensembles in schools. It is not possible to quantify the number of conductors in total in Canada, but some more numbers can be assembled by analyzing the individual groups. For example, there are approximately 14,600 elementary and secondary schools in Canada (Council of Ministers of Education Canada, 2021), with about 75% having at least one dedicated music teacher (Hill Strategies Research, 2010). With music being a mandatory subject in the curriculum from kindergarten to grades 6-10 (depending on the province; Hill Strategies Research, 2010) there are many teachers teaching music in schools that would use some type of conducting in their classroom. Also, there were approximately 140 members of Orchestras Canada, the non-profit organization for Canadian Orchestras during their 2018-2019 season, the last season for which data are published (Orchestras Canada, 2019). Although this does not represent all the professional and youth orchestras in the country given participation with Orchestras Canada is voluntary, it represents a noteworthy number of Canadian Orchestras, each with their own conductor.

### *2.2 Work-related Musculoskeletal Disorders*

The ability to produce and execute movement is an integral part of every-day human life. Seemingly simple tasks require the complex interaction of numerous different joints, muscles, ligaments, tissues, and the systems that control them (Robertson et al., 2014). Anytime we execute movement, there is a possibility for an injury to occur, but some situations provide a higher level of risk for WMSD than others. An injury is defined as damage experienced by the body's tissues in response to physical trauma (Whiting and Zernicke, 2008). A WMSD is a specific type of injury that occurs to the musculoskeletal system due to risk factors associated with work-related tasks. There are four main categories of risk factors for WMSDs: psychological risk factors, individual risk factors, physical risk factors (Kumar, 2008), and environmental risk factors (Whiting and Zernicke, 2008). Although there are many unique risk factors, most can be sorted into one of these four categories.

A psychological risk factor is a behavior or psychological characteristic that has been scientifically shown to increase the likelihood of developing a specific WMSD (Kumar, 2008). They may not be high on the list of considerations when assessing risks for a physical WMSD, but they can play a consequential role. An individual's psychological state before, during, and after a WMSD can affect if or how they get injured and how they recover (Whiting and Zernicke, 2008). Life stress and change, as well as job stress and change, are two common psychological risk factors that increase the likelihood of an injury (Whiting and Zernicke, 2008). Anxiety, depression, and job dissatisfaction can also play a role (Davis, 2000; Kumar, 2008).

Individual risk factors include physical and genetic differences between individuals that are known to affect the likelihood of developing a WMSD (Kumar, 2008). Each person's body is shaped differently. Externally, one person could have different proportions compared to another, and these differences are apparent inside the human body, as well (Kumar, 2008). Many of these physical differences could be present without anyone even knowing, and they generally are not something we can actively change without major surgery (Kumar, 2008). For example, two individuals might have differently sized spinal columns, or differently sized trunks compared to their leg lengths. These differences could present possible injury risks (Kumar, 2008). Also, different genetic make-ups and disease predispositions (as disease (e.g. osteoporosis) may increase the risk of an injury (e.g. broken bones)) are individual risk factors (Kumar, 2008; Whiting and Zernicke, 2008).

Environmental risk factors are numerous and can further augment the risk of injury when combined with other risk factors (Whiting and Zernicke, 2008). Characteristics of the environment in which an activity is completed may increase or decrease the likelihood of developing a WMSD (Whiting and Zernicke, 2008). Factors like weather conditions, amount of light, altitude, and type of terrain or floor surface present possible risk factors and may be challenging or impossible to change or control for (Whiting and Zernicke, 2008). Changes in environmental conditions throughout an activity (such as a change between a practice and performance environment) can be challenging to adapt to and provide an extra strain on an individual, affecting their risk of developing a WMSD (Bird, 2016; Lee et al., 2020).

Finally, physical risk factors include external factors and forces that have been scientifically shown to affect the likelihood of developing a WMSD (Kumar, 2008). Injury or physical damage to the tissue occurs when the load placed on the tissue is greater than the load the tissue can tolerate (Kumar, 2008). This can occur cumulatively over time (as is the case with a chronic injury), or immediately (as is the case with an acute injury) (Schmitt et al., 2019). Physical risk factors can be further categorized and identified as force, posture, and repetition (Potvin, 2014).

### 2.2.1 Force

Force is defined as an action that causes bodies to be pushed or pulled in different directions (Frievalds, 2018). A single application of high-magnitude force can cause an acute injury by overloading the tissue’s capabilities, and repeated applications of low-magnitude forces can cause chronic injury by placing cumulative stress on a tissue over time, which reduces the tissue’s capability to withstand forces (Whiting and Zernicke, 2008). When a force is applied to the human body, a transfer of energy occurs between the force being applied and the body’s tissues. Different tissues have different capabilities for force absorption and energy dissipation, and the body may also be protected by external structures or padding that are designed to reduce the risk of injury (Committee on Trauma Research, 1985). When a tissue is required to absorb and dissipate more energy than it is designed to handle, it becomes deformed beyond the point from which it is possible to recover, and an injury is caused (Committee on Trauma Research, 1985). Damaged tissues will have decreased capabilities and will fail or get injured more quickly (Whiting and Zernicke, 2008).

A wide range of studies show that the risk of injury, and the severity of the resulting injury, increase as an increased amount of force is applied (Adamec et al., 2013; Bates et al., 2013, Skotte and Fallentin, 2008). For example, healthcare workers are required to physically move and support their patients multiple times each day. During patient repositioning, healthcare workers working with patients with higher body masses experienced significantly greater low back compression forces, even if they were using assistive devices like sliding sheets (Skotte and Fallentin, 2008). The act of ball-heading in soccer is another example, and it provides a unique opportunity for study as the brain is a very important and complex organ that is protected inside the thick, bony skull. When participants with and without soccer ball-heading experience headbutted a human representation, the force produced increased as the head's velocity increased (Adamec et al., 2013). The higher force led to a greater chance of injury, although the injury risk at the velocities studied were all non-life threatening (Adamec et al., 2013). Other injuries to the bony structures in the skull were also present after the headbutting incidents. Two significant reviews of the literature (Bernard et al., 1997: 600 studies; da Costa and Vieira, 2010: 1761 studies) identified excessive force as a potential WMSD risk factor, and further research continues to describe the relationship more thoroughly.

Conducting itself does not involve any substantial lifting or the application of large external forces, but the cumulative effects of the inertial forces generated during upper limb movement patterns, and moving the limbs against gravity over time, could lead to WMSD risks that are worth exploring in future studies.

### 2.2.2 Repetition

Repetition is defined as the act of completing the same movement or motion multiple times within a specific time frame (Gallagher and Heberger, 2013). It leads to increased WMSD risk by continuously using the same muscles and ligaments in the same movement patterns over a long period of time without giving them adequate time to rest and recover (Freivalds, 2018). At the beginning of a repetitive period, muscles and tendons begin to adapt to the repetitive workload by increasing the number of capillaries and the amount of blood flow to the area (National Research Council, 2001). Once a critical point is reached in the injury process, the positive aspects of extra blood flow are replaced with the infiltration of cells responsible for the inflammatory response, leading to the styles of WMSDs associated with repetitive strain (Whiting and Zernicke, 2008).

Repetition is a risk factor that can closely relate to other risk factors. For example, when a specific movement is repeated under a heavy load or force, the risk of a musculoskeletal disorder increases significantly compared to the same movement being completed under light or no load (Gallagher and Heberger, 2013). Even without the addition of a heavy load or force, the cumulative effects associated with repetition, especially in non-neutral postures, provides significant risk for injury (Frevialds, 2018). In two significant reviews of the literature, repetition was identified as a risk factor for WMSDs both by Bernard et al. (1997) and da Costa and Vieira (2010). This was true when analyzing the whole body overall, as well as when specifically analyzing studies with findings on the shoulder and hand/wrist.

Repetition is ingrained into the entire structure of learning and improving on a musical instrument (Bird, 2016; Lee et al., 2020). Students are taught from a young age that it is important to practice a substantial amount every day, with hours spent practicing, performing, or in rehearsals increasing as their level of proficiency increases. Repetition has been identified in the performance of multiple musical instruments including string instruments (Hopper et al., 2017; Shan and Visentin, 2003), the drum set (Flammia and Azar, 2021), and wind instruments in a marching band setting (Beckett et al., 2015). Three-dimensional motion capture was used as a part of a multi-dimensional signal analysis to identify the repetitiveness involved with performance on the violin (Shan and Visentin, 2003). Repetitiveness was also visually identified in a study of the kinematics of the upper limbs while playing the drum set (Flammia and Azar, 2021) and in other studies investigating injury rates and patterns in musicians (Beckett et al., 2015; Hopper et al., 2017). Although official causation cannot be claimed, there is a significant positive correlation identified in the literature between the repetition identified and associated injury rates.

Repetition has been positively associated with the development of musculoskeletal discomfort and WMSDs in musicians (Beckett et al., 2015; Hopper et al., 2017; Shan and Visentin, 2003), but it has not been thoroughly investigated in conductors. With the basic conducting pattern being repeated from start to finish of each musical piece conducted, repetition is clearly a part of the conductor's job description. Further quantifying and describing a conductor's experience with repetition throughout their performance will aid future researchers in making suggestions to reduce the significance of this injury risk. Given that it is so engrained into musical culture, understanding repetition from a biomechanical research perspective requires the coordination and teamwork between many multidisciplinary professionals using different styles of assessment (Shan et al., 2004).

#### 2.2.3 Posture

Posture is a term used to refer to the position of your body (Jaffar et al., 2011). Although everyone has different preferences, an awkward posture is one in which there are excessive amounts of uncomfortable twisting or bending, and a static posture is one that is held for a substantial period of time (Jaffar et al., 2011). Awkward postures require an increased energy expenditure to maintain and place increased stress on the involved tissues, thus increasing the risk of injury (Kumar, 2008). The pain one may experience after holding an awkward posture for a long period of time is only the first step along the path to developing a WMSD. Static postures require an individual to be stationary for long periods of time, reducing the circulation of blood through the muscles and surrounding tissues (Tortora and Nielsen, 2014). Muscles and other tissues are not able to receive the oxygen and nutrients they require, and the waste products produced by the tissues are left stagnant and not effectively removed. Continued loading under these conditions leads to damaged tissues and injuries (Whiting and Zernicke, 2008)

In a review of the literature investigating risk factors in the construction industry, posture was identified as having significant potential to cause musculoskeletal pain and injury (Jaffar et al., 2011). Specific movement patterns in the upper limb were identified to be some of the leading causes of pain. These included frequent reaching overhead, flaring of the elbows away from the body, and frequent bending at the wrist (Jaffar et al., 2011). In reviews of the literature overall at two separate points in time, Bernard et al. (1997) and da Costa and Vieira. (2010) identified posture as a strong risk factor in the development of injuries both in the shoulder and the hand/wrist. It was noted that extreme postures were often combined with other risk factors, such as repetition or force, to cumulatively increase injury risk.

Posture is a risk factor that has been studied in instrumental musicians, specifically ones that play the violin and piano. Pianists spend long hours at their instrument often sitting with an unsupported trunk (Pappa et al., 2020). When comparing beginner adolescent pianists to advanced adolescent pianists, it was identified that the advanced pianists remained in a more neutral trunk and upper limb posture and exhibited significantly less sway compared to their beginner counterparts (Pappa et al., 2020). The advanced musicians' movements were more purposeful whereas the beginners' movements exhibited a larger range of motion (Pappa et al., 2020). The increased experience and longer time in lessons was identified as a driver behind the more ideal posture identified in the more experienced musicians (Pappa et al., 2020). This highlights the importance of educating individuals on proper posture and continuing to stress it throughout their training. In a larger study investigating the postural habits of orchestral violinists, it was identified that there are a significant number of postural habits that professional musicians unnecessarily carry with them into performance (de Araujo et al., 2009). Although these musicians are no longer taking lessons, and no longer have that regular time working with a teacher who can identify poor postural habits, external postural cuing clearly remains an important aspect of regular practice even when musicians reach the self-directed portion of their career (de Araujo et al., 2009). Percussionists present a unique case because they use a larger portion of their body regularly in rehearsal and performance (Coker et al., 2004) and non-neutral postures can contribute to the development of musculoskeletal disorders, especially in the upper limbs (Flammia and Azar, 2021). As the musicians gain more experience, posture is something that is overlooked as more emphasis is placed on other areas of performance. As the musicians work through long practice sessions, they become physically fatigued, which was shown to negatively affect posture (Coker et al., 2004).

When conducting, all the body's moving parts are directly connected, so misalignment or poor posture in one section will affect the entire movement pattern (Jordan, 2009). Bad postural habits can be very challenging to break. A deep kinesthetic awareness and ability to "feel the groove" is also an integral part of the conductors' ability to clearly communicate non-verbally with their musicians, but it is also something that can be negatively affected by a conductor's poor posture and rigidity (Jordan, 2009).

Posture has been shown to play a role in the musculoskeletal discomfort and WMSDs in musicians and it can be connected to the movement patterns and non-verbal communication style required to be an effective conductor, but its effects on conductors has not been investigated thoroughly. With the physical demands of conducting, including the sustained holding of specific upper-limb postures (e.g., shoulder muscle tension while holding up the upper limbs throughout a performance), it can be compared to musical performance on other instruments. Further investigation into the kinematic demands of conducting would allow the job to be more accurately quantitatively described. This would ensure that any potential impacts of posture on the long-term health of conductors can be studied if necessary.

## *2.3 Work-related Musculoskeletal Disorders in Different Occupational Groups*

### 2.3.1 Conductors

The rates and patterns of work-related musculoskeletal disorders (WMSDs) in conductors is not a topic that has been extensively and formally researched, although it is a common topic in musical journals and popular magazines. WMSDs can be experienced by professional and amateur conductors alike and can be career-ending phenomena (Hollaway, 2006; Robb, 2018).

For professional or semi-professional conductors, the potential of getting injured is an unnerving thought. Guptill (2011) analyzed the experience of professional musicians experiencing playing-related injuries.  In a highly competitive field like music performance, musicians (a group of professionals that can broadly include conductors as well) reportedly are hesitant to show "weakness" and ask for help with an injury, WMSD, or other discomfort, as they are concerned that their employer may begin to look for possible replacements or their peers may begin to think less highly of them (Guptill, 2011; Lee et al., 2020; Sauter and Murphy, 1995).  A moment of "weakness" could lead to the loss of a job, which then presents a loss of income, loss of health insurance, and potential loss of identity the conductor associates with their job.  Introductory research in conducting kinematics could lead to further research into WMSD risk factors, treatment, prevention, and education strategies to reduce the risk of WMSDs in conductors and normalize the discussion of performance-related injuries between employers, peers, and healthcare professionals.

There has been very little formal research completed to date that has analyzed the kinematics of conducting of any style or investigated the rates of WMSDs experienced by conductors.  Beckett et al. (2015) and Moffitt et al. (2015) both designed surveys to investigate the rate of injuries in collegiate marching band members including drum majors (the specific name for marching band conductors who work with the band in performance settings).  Although kinematics were not analyzed and risk factors can only be assumed, Moffit identified drum majors (representing approximately 2 % of the population studied) as having the lowest injury incidence rate out of the 154 participants surveyed (2015).  Conversely, Beckett et al. (2015) identified drum majors (representing approximately 1.2 % of the population studied) as one of the sections with the highest injury incidence rate in their survey of 1379 participants.  Compared to standard conductors, drum majors use conducting patterns that are more regimented and stricter, so it is challenging to directly compare the kinematics of the two groups. However, these differences in study results highlight the possibility for injury in conductors in general, and the importance of further in-depth research.

Luger and Trouli (2023) investigated the health of conductors using a 47-item online questionnaire and included incidence of conducting-related musculoskeletal disorders. With a notable prevalence (67.4%) of WRMSDs reported among the 172 participants, the upper limbs (specifically the right side) were found to be the body part most affected. The participants in the study were all relatively young, so it is noted that this percentage may even be higher in this population if the age of the participants was more representative of the entire population of conductors.

Some studies involved the collection of kinematic data specifically for the analysis of the relationship between a conductor's movement patterns and the resulting performance from the musical ensemble being conducted. These studies applied a case study approach with a limited number of participants. Huang et al. (2017) analyzed the kinematics of the tip of six conductors' batons and determined that their movement patterns were directly related to the predetermined musical intentions they were tasked with communicating. Schallert (2020) analyzed the kinematics of the tip of a baton of one experienced orchestral conductor conducting pre-determined patterns of staccato (short, detached) and legato (smooth, connected) notes for the purpose of identifying perceived effectiveness (Schallert, 2020). The author demonstrated that the patterns involving staccato notes had an increased range of motion in the vertical plane and patterns involving legato notes had an increased range of motion in the horizontal plane

(Schallert, 2020). However, examining performance kinematics in the context of injury prevention was beyond the scope of these studies.

### 2.3.2 Other Musicians

Piano players have presented with a wide range of musculoskeletal complaints, primarily in the trunk and upper limbs (Monino et al., 2017). In reviewing performance kinematics, repetition was highlighted as one of the primary injury risk factors (Monino et al., 2017). The unnatural postures and intensity of movements led the researcher to compare piano performance to athletic activities. The musicians who participated in this study expressed the feeling of a lack of support identifying the need for continuing education (Monino et al., 2017).

When investigating the kinematics of violin performance as a base for future research on overuse syndrome, Shan and Visentin (2003) identified many similar movement patterns between musicians of different sizes once values were normalized for body height. They found that wrist movement patterns varied significantly between musicians and did not follow any general pattern. The right upper limb patterns varied significantly when the musician played on different strings (especially at the shoulder and elbow), but as expected this did not affect the movement patterns seen in the left upper limb as the left upper limb is primarily responsible for holding the instrument.

Hopper et al. (2017) identified that cellists experience a static left rotated torso and high degrees of combined shoulder flexion and internal rotation. Awkward postures increased as the volume of the performance increased and high levels of repetition were identified, similar to the studies completed on pianists and violinists (Hopper et al., 2017).

All instruments require a different performance posture and style, so their injury risk factors vary greatly, and specific research is required to ensure appropriate recommendations can be provided.  The drum set is an instrument on which very little research has been completed.  A survey-based investigation of drummers' experiences with playing-related musculoskeletal disorders (PRMDs) identified that 68% ($N$ = 831) of respondents identified a lifetime history of these injuries, with the upper limb being the most common location (59%).  A kinematic analysis of the upper limbs while playing the drums quantitatively highlighted the amount of repetition and non-neutral postures required to perform on the instrument (Flammia and Azar, 2021).  For example, it was identified that a substantial amount of time during performance is spent with the wrist in extension (right: 95%, left: 96%).

All four previously mentioned instruments are performed in a seated position, but conducting generally requires the individual to stay standing in an upright position, similar to musicians in a marching band.  As with other instruments, repetition was identified as a key factor in the development of a musculoskeletal injury in marching band musicians (Beckett et al., 2015; Moffit et al., 2015).  Although it was not feasible to collect motion capture data on all members of the marching bands studied, it is still clear from observing the musicians perform that repetitiveness and specific prescribed postures can lead to future injury (Beckett et al., 2015; Moffit et al., 2015).

### 2.3.3 Comparable Jobs

Given that there is very limited literature on the kinematics of conducting, a lot can be learned from investigating other similar jobs that require similar upper limb movement patterns. Conducting features substantial upper limb movement directly in front of the body while remaining cognitively engaged and upright in a standing position.  This can be compared to the work done by a grocery store cashier, and to light manufacturing work done in a factory setting.

Cashiers are responsible for scanning items and moving them from a conveyor belt on one side of their body to the other side. Extensive amounts of reaching and grabbing play a role when the cashier helps bag the customer's groceries. Lang et al. (2018) quantified cashiers' upper limb movement as they bagged groceries at various workstation heights using different styles of containers (e.g., plastic bags or boxes). The authors reported that a workstation that was too high for an individual employee caused an increase in the employee's discomfort after a shift of grocery bagging. They also reported that the employee experienced decreased shoulder internal rotation and upper limb elevation when they adjusted their workstation to a lower level when packing taller containers. Lang et al. (2018) concluded that giving the employee the opportunity to adjust the workstation and the training to understand what position was the most physically appropriate reduced their risk of injury. Through kinematic analysis, Draicchio et al. (2012) identified that cashiers who stood during their shifts had better reaching mechanics and spent reduced amounts of time in awkward postures than those who used chairs. Algarni et al. (2020) reported that frequent rotation of the neck led to this being one of the body regions with the highest injury rate in cashiers. Thus, variable workstation heights and decreased repetitiveness could potentially result in a reduction of WMSDs experienced by grocery store cashiers.

Like cashiers, the high level of repetition and awkward postures identified in factory work likely play a role in employees' development of musculoskeletal complaints (Schall et al., 2021; Wei and Shi, 2013). Repetition was identified as a greater risk factor in individuals who worked completing cyclic tasks, compared to individuals who completed non-cyclic tasks (Schall et al., 2021). The lack of adaptability in the workstation of a shearing machine increased the injury risk for some employees, but not all, as some had body sizes and anthropometrics that allowed them to complete the task comfortably, whereas others had to assume uncomfortable postures (Wei and Shi, 2013). Factory workstations differ significantly both between and within individual locations or companies. Although the movement patterns may be similar between conducting and light manufacturing and grocery cashiers, conductors have an advantage in that (in most cases) they have more control over their own workstation.

Work done by grocery store cashiers and in light manufacturing highlights the variability seen in the workplace between individuals and different settings that is also seen in conducting. Although these jobs require similar movement patterns, each has its own unique challenges and the findings of studies completed in the grocery store or factory highlight the importance of learning more about the kinematics of conducting.

### *2.4 Tools and Instrumentation – What is Motion Capture?*

Kinematic analysis can be used to quantitatively describe the movement we see (Robertson et al., 2014). With a better understanding of how our bodies move – what postures we spend most of our time in, how frequently we bend our elbows, or the range of motion of our shoulder, for example – we can make better, evidence-based plans to ensure we continue to be able to move comfortably without incurring new WMSDs or making existing ones any worse. To describe or better understand any kind of movement pattern, researchers need to be able to quantify it and measure it. When assessing the kinematics of human movement, this quantification and measurement is completed using motion capture systems (Robertson et al., 2014). These systems have both hardware and software aspects and are a valuable tool in biomechanics. They allow for the capture of movement patterns for further analysis through the recording of the movement of markers attached to specific locations on the participant being studied (Robertson et al., 2014). Following data collection, manual or automatic digitization of the data is completed to determine the coordinates or locations of each of the markers within two- or three-dimensional space. Although this used to be a manual (and very time consuming) process, most current motion capture systems feature automatic digitization capabilities (Robertson et al., 2014).

Depending on the software or programs used with the kinematic data collected, motion capture systems can produce a wide range of valuable information, including joint angles and segment positions, velocities, and accelerations (Robertson et al., 2014). Motion capture hardware can also be used together with animation software to produce animated figures with human-like movement patterns.

### 2.4.1 Types of Motion Capture Systems

There are three main types of motion capture systems: retroreflective, optoelectronic, and inertial measurement unit (IMU) systems. Retroreflective and optoelectronic motion capture systems rely on the use of cameras and a set of markers (Robertson et al., 2014) to collect kinematic data. In both cases, an array of cameras is set up around the study participant to record the movement of the markers placed on the participant's body in specific locations (Robertson et al., 2014). Multi-camera setups are required for three-dimensional motion capture, so the position of the markers is collected from a variety of different angles. This multi-camera setup also helps keep the markers in constant view, because when the participant is in certain positions, markers may become blocked from view of the camera by other body parts. There are many settings to consider when using cameras with a motion capture system (Robertson et al., 2014).

Retroreflective and optoelectronic systems differ in the makeup of their markers. Retroreflective systems feature reflective markers and rely on a light-emitting camera or other external light sources to provide the light for the markers to reflect (Festo, 2021). Optoelectronic systems feature active markers that emit a source of reflective light themselves (Winter, 2005). Both these styles of systems are time consuming to set up (Perrott et al., 2017) and require expensive laboratory equipment and highly trained personnel (Bolink et al., 2016; Winter, 2005). The multi-camera systems are expensive and most are not mobile (i.e., they must be installed in a lab and remain there; Bolink et al., 2016; Winter, 2005). Accurate measurement relies heavily on the input from the motion capture system's camera to measure the position of each marker (Topley and Richards, 2020), which can be problematic if there are objects or other people blocking the camera's view of the markers. The designated labs or spaces these systems require provide a stable environment with minimal disruptions, likely improving the efficacy and accuracy of data collection. As the "gold standard" for motion capture, these systems have been relied upon in research for decades, increasing the quantity and depth of available research publications.

The third type of motion capture system is an inertial measurement unit (IMU)-based system. IMUs provide the opportunity for kinematic analysis without some of the restrictions present with gold-standard optoelectronic or retroflective motion capture systems (Bolink et al., 2016). They are not only used in biomechanics, though, and can provide accurate tracking in drones, unmanned aircraft, and in GPS units when satellite connection is weak. Borrowed from the aerospace and engineering fields, IMUs provide motion tracking opportunities without some of the restrictions present in typical laboratory systems (Cuesta-Vargas et al., 2010). Although they are more flexible and can be easily used outside of a formal laboratory, they also require an increased amount of time to set up. Given that they are a newer motion capture option, there are limited studies highlighting their reliability and validity in different settings.

2.4.2 Xsens MVN Awinda™ Motion Capture System and MVN Analyze Software

The Xsens MVN Awinda™ motion capture system is a tool that allows researchers to collect motion capture data using 17 wireless IMUs and a strap-based set up that makes it adjustable for research participants of varying sizes. The 17 wireless tracker units include micro-electromechanical systems (MEMS) based IMUs with three components: an accelerometer, magnetometer, and a gyroscope (Schepers et al., 2018). These components work together to overcome their respective shortfalls to develop data points (Schepers et al., 2018). For example, the data collected by the magnetometer (which takes measurements relative to magnetic north) compensates for the measurements taken by the gyroscope (which measures angular velocity or rotational motion), as gryoscopes are more prone to drift.

The benefits of this specific system are that it is portable and is designed to be used outside of the laboratory environment. By collecting data on participants in their own natural working environment, more ecologically valid data can be collected because the participants will be familiar with and comfortable in their surroundings. The Velcro™ straps used to attach the IMUs are simple to apply and can hold the sensors securely while the participants perform their required movements. The calibration process is straightforward to initiate and can be repeated throughout the data collection process as necessary. Finally, one of the major benefits of the Xsens™ system is the lack of required cameras. Not only does this reduce the setup time, but it also allows continuous data to be collected even when objects are present in the environment that could potentially obstruct the view (e.g., music stands, other musicians).

The Xsens MVN Awinda™ hardware has been shown to be both reliable and valid in collecting kinematic data outside a laboratory setting (Al-Amri et al., 2018; Cutti et al., 2008; Khurelbaatar et al., 2015; Mavor et al., 2020; Robert-Lachaine et al., 2017). When values collected with the Xsens™ system were compared to values collected with another standard optical motion capture system for participants completing whole-body tasks, only minimal differences between the two datasets were noted (Mavor et al., 2020). The Xsens MVN Awinda™ system was also found to be reliable, as data collected on repeated participants over a multi-day study in a rehabilitation clinic, were found to be very similar with fair-to-excellent reliability (Al-Amri et al., 2018).

However, when comparing data produced by the biomechanical models built into the Xsens MVN Analyze ™ system compared to a gold standard motion capture system, Mavor et al. identified a significant difference in RMSE of 21.6° between the values for the upper limbs (2020). These results may be challenging to interpret, because the values identified by the Xsens MVN Analyze ™ system were compared to values identified by another data collection system and biomechanical modeling program with their own sets of potential errors, as opposed to being compared to "true movement" (Mavor et al., 2020). The potential shortcomings of the biomechanical model built into the Xsens™ software system are important to acknowledge because the movement patterns executed by conductors rely heavily on their upper limbs. However, Xsens™ developers have made improvements to the biomechanical models of the upper limbs since Mavor et al. (2020) collected their data (L. Abraha, personal communication, August 16, 2021). Furthermore, Xsens™ systems have been extensively used in recent sport science research studies (Blair et al., 2020; Klitgaard et al., 2021; Pedro et al., 2021; Setuain et al., 2017). The sports analyzed included on-water kayaking (Klitgaard et al., 2021), Australian football (specifically kicking: Blair et al., 2020), serving in tennis (Pedro, 2021), and sprinting and return to play post-acute injury in soccer (Setuain et al., 2017). In all these sports, it is challenging or outright impossible to replicate an appropriate environment in a structured biomechanics lab, which is limited in space and climate. With the Xsens's ™ portability, the researchers were able to meet their participants in their own performance environment, ensuring the data collected were as close to real-life quality as possible. The Xsens™ was also able to easily capture data from body parts that may have otherwise been visually blocked, such as when a participant is seated in a canoe. This allowed the researchers to collect a full set of data without extrapolating or guessing when data were missing.

Given the current lack of kinematic research on conductors, the benefits of using the Xsens MVN Awinda™ system clearly and substantially outweigh the limitations of using the associated MVN Analyze biomechanical model.

### *2.5 Labelling Postures*

Labelling postures or the static positions of the body in the workplace is a method used to help determine the level of risk associated with a particular job or task. These labels are assigned by a trained professional using research-based assessment tools, and these professionals can make their measurements and observations without having to participate in the task in its entirety themselves. One example is the Rapid Upper Limb Assessment (RULA: McAtamney and Corlett, 1993).

The RULA is an ideal tool for documenting task-related postures because it does not require any special equipment, can be completed only through observation, and is relatively quick to complete (McAtamney and Corlett, 1993). It was developed based on pre-defined risk factors and was designed in multiple phases. It is generally used to analyze only the most severe posture assumed during a movement or task (McAtamney and Corlett, 1993), although recent studies have used it to assess kinematic data time histories (i.e., joint angles: Plantard et al., 2017; Humadi et al., 2021). Along with qualitative assessments of muscle use (i.e., static or repetitive) and the contribution of holding loads or forceful exertions, RULA uses posture bins that together form a final score identifying the urgency of posture adjustment to improve the safety of a particular task (McAtamney and Corlett, 1993).

McAtamney and Corlett (1993) claim that the RULA is reliable, and it was found to have a fair inter-rater reliability (Robertson et al., 2009). It is specified that it is not supposed to be the only tool used in determining the level of safety of a particular job (McAtamney and Corlett, 1993). It was not designed specifically with conductors in mind, but it is a frequently used, well recognized postural assessment tool.

### *2.6 Summary*

Music education provides an opportunity to learn many important life lessons beyond how to assemble an instrument and produce beautiful music, and conductors play a huge role in facilitating these learning opportunities. With numerous risk factors like awkward postures and high levels of repetition visible, increased research surrounding WMSD risks while conducting would be advantageous to help keep this population healthy. Fully understanding and being able to describe the kinematics of conducting will provide a foundation for evidence-based recommendations for this community.

# CHAPTER 3

# METHODS

## *3.1 Participants*

### 3.1.1 Target Population

The participants in this study included professionally established conductors in the Windsor-Essex or Chatham-Kent regions. The target population included both professionally established conductors and post-secondary students currently enrolled in conducting studies, but no students were successfully confirmed as participants as they must have been currently enrolled in a university-based music program and taking (or have completed) at least one single semester course in conducting and be identified as a student-conductor in a music performance credit course or ensemble.

A goal of five participants was set, and data were collected from a total of seven participants. As the research in this area is limited, data from five participants will significantly improve the base of knowledge while still being a realistic goal with COVID-19 safety measures and the limited number of sufficiently experienced conductors within the Windsor-Essex and Chatham-Kent regions.

Seven conductors of choral ($n$ = 2) or instrumental ensembles ($n$ = 5) participated in this study (6 males, 1 female). Recruited from Windsor-Essex and Chatham Kent, they had an overall mean (± SD) age of 59.1(12.6) years, height of 176.6 (5.1) cm, body mass of 90.6 (17.0) kg, and years of experience conducting of 32 (16.5).

### 3.1.2 Inclusion Criteria

To participate in this study, individuals met the following criteria:

- Be at least 18 years of age or older
- Be free from any kind of upper body injuries in the past 12 months that impacted their activities of daily living or their ability to conduct their ensembles
- Have professional training in conducting such as a university music degree or professional mentorship
- Conduct a group of musicians at least once weekly, for at least two hours (total) each week while in their regular practice season
- Work regularly with the same group of musicians in a practice setting where the research team could attend to complete data collection

### 3.1.3 Exclusion Criteria

Participants were excluded from the study if the research team identified them as ineligible based on meeting any of the following criteria:

- Are under the age of 18 years
- Have experienced an upper body injury in the past 12 months that impacted their activities of daily living or their ability to conduct their ensembles
- Do not have sufficient professional or volunteer experience as a conductor
- Do not work with a group of musicians at least once a week for at least two hours each week during the regular practice season in a setting where the research team can safely complete the data collection process
- Are allergic to the adhesives possibly used during data collection

### 3.1.4 Informed Consent

Informed consent was obtained in writing from each participant before each data collection session began. Musicians in the ensemble conducted by the participant were informed of the date of the data collection in advance (verbally and over email) and were given the opportunity to sit out. In ensembles with musicians under the age of 18 years, their caregivers were also notified about the data collection by email. To the best of the PI's knowledge, no musicians chose to sit out during the data collection. Hard copies of the Informed Consent Form (Appendix A) were signed before in-person data collection commenced.

## *3.2 Instrumentation*

### 3.2.1 Xsens™ Hardware and Software

The Xsens MVN Awinda™ (Xsens, Enschede, Netherlands) motion capture hardware was used for data collection. The full system includes 17 IMUs (dimensions of each unit: 47 mm x 30 mm x 13 mm, mass: 20 g) to record the movement of the entire body, but only 11 IMUs were used in this study to track the movement of the upper body and limbs superior to the pelvis (Xsens, 2021). The sensors were placed as shown in Figure 2, but those shown on the lower limbs were omitted. This reduced setup decreased the amount of time required for instrumentation and calibration, thereby improving the efficiency of data collection and decreasing the amount of time the researcher and participant had to spend physically closer than recommended according to COVID-19 safety guidelines. This also respected the participants' time as they prepared for their rehearsal. The "no level" recording setting was used as the participant was not interacting with their environment.

Figure 2: Anterior (left) and posterior (right) views of two individuals fully instrumented with all 17 IMUs. For this study, only the IMUs above the pelvis were used (Xsens, 2021; Xsens, 2016).

The IMUs communicate with the software that was used (Xsens™ MVN Analyze, Enschede, Netherlands), at a rate of 60 Hz at a maximum distance of 20 metres indoors. Data were processed using the built-in biomechanical model of the MVN Analyze software. The sensors acquired data at a sampling rate of 1000 Hz, and the data underwent a proprietary strapdown integration (SDI) procedure prior to wireless transmission from the sensors to the Awinda receiving station at a rate of 60 Hz (Schepers et al., 2018; Xsens MVN User Manual Revision Z, 2021).

### 3.2.2 Other Equipment

A body mass scale and flexible tape measure were used to collect relevant anthropometric values from each participant, as well as specific measurements required for the biomechanical model in the Xsens™ MVN Analyze software. A laptop computer was used to run the MVN Analyze software in a portable manner.

A video camera (e.g., Sony Handycam) was also used to record each data collection session. The video recordings were not directly used in data analysis but provided an alternative view and record of the data collection session so any anomalies and unexpected movements could be easily identified.

## *3.3 Procedures*

A flow chart depicting the data collection process from start to finish can be found in Appendix B.

### 3.3.1 Recruitment

Participants were recruited through email, word of mouth, social media posts (Facebook/Twitter/Instagram), and posters displayed in prominent music-based locations around the city and on campus such as music stores and performance venues. Approval was obtained (and cleared with the University of Windsor's Research Ethics Board) through each music group or organization before their conductor (the potential participant) was approached. This extra step was skipped if the participant approached the PI directly.

### 3.3.2 Before Data Collection

Once a potential participant expressed interest and initiated contact over email, they were screened for inclusion/exclusion criteria and a letter of information about the study was shared. The potential participant was invited to have any questions answered by the investigator. If they chose to proceed, two separate mutually convenient data collection time slots were identified: the first for a brief telephone or video call interview and the second for in-person data collection.

Participants were provided with important information by email once their participation was confirmed to ensure they had adequate time to make all necessary arrangements. They were instructed to select approximately 15-30 minutes of music that was used for the data collection process. This music was at an appropriate level for their ensemble and was something that their ensemble could comfortably play through at a near performance-ready level of proficiency at the time of data collection to reduce the amount of stopping and starting. The music selected required conducting patterns typical of the participant's regular rehearsal.

#### 3.3.3 Initial Interview

The first data collection session involved a brief interview completed over the telephone or video conferencing software (e.g., Microsoft Teams) at the preference of the participant. Before the interview started, the participant had the opportunity to ask any remaining questions, and they were asked to provide verbal confirmation that they read the letter of information shared by email and consented to the collection of data.

A selection of questions was asked of the participant (Appendix B). These questions were designed to gather information on the participants' experience in conducting, injury history and risk factors, and information about the type of ensembles with which they work. At the end of the interview, the participant was provided with important reminders about the next data collection date. Time and location were confirmed, and the participant was instructed to inform their ensemble (verbally and over email) if they had not already done so. This allowed individuals in the ensemble to choose to sit out if they wanted to. For the in-person data collection session, participants were instructed to dress as they normally would to conduct, but to wear flat-soled shoes and a shirt that could accommodate the IMUs attached with straps or adhesive tape and that would not be damaged by the adhesive tape, should it be needed. The investigator brought a cotton unisex-fit t-shirt into which the participant could change and keep once data collection was complete, if they were worried about damaging their own clothing.

### 3.3.4 In-person Data Collection Session

The second data collection session occurred in-person at the ensemble's rehearsal space. Before the data collection session started, the participant was introduced to the investigators and was given the opportunity to have any questions answered. The participant was asked to fill out physical copies of the informed consent form (Appendix A) at that time. The investigator introduced herself and the research team to the ensemble and explained the data collection process, giving ensemble members the opportunity once again to leave the room if they were uncomfortable with being present during data collection.

The anthropometric measurements required for the biomechanical model were taken once. These measurements were entered into the MVN Analyze software to scale the biomechanical model to the participant. A chart describing the measurements that were taken can be found in Appendix D. Prior to data collection commencing, a brief study was completed analyzing the investigator's accuracy in completing the anthropometric measurements required for use with the MVN Analyze biomechanical model, and an error rate of less than 1.3% was identified. The measurements were completed 3 times each, in a randomized order, on 10 student volunteers from the Faculty of Human Kinetics. Results can be found in section 4.9.

Next, the participant was instrumented with the Xsens Awinda™ hardware on their trunk and upper limbs with IMU placement as shown in Figure 2 in section 3.2.1. Stretchy bands affixed with Velcro™ that are a part of the Xsens™ system were used to attach IMUs to the upper limbs and pelvis, medical grade adhesive tape (e.g., Hypafix) was used to attach IMUs to the sternum and scapulae in instances where the provided shirt with built-in Velcro attachments did not fit, and a stretchy headband was used to hold an IMU against the back of the participant's head. Fingerless gloves were used to attach a sensor to each hand. The participant was given some time to move around with the IMUs on to ensure they are comfortable, and any adjustments were made, prior to starting data collection. The calibration process was then completed. The calibration process involved a brief period of standing in a neutral position followed by a short length of walking and moving around the space, and then a return to the neutral position. The participant was instructed to walk around for approximately 30 seconds to warm up the system while the investigators ensured the participant's on-screen model looked as expected. Recalibration occurred, as necessary, until the calibration reading was identified as appropriate, and any remaining equipment (such as the video camera) was set up by the research team.

Finally, the participant executed their performance protocol. They conducted their ensemble through the selection of songs they identified and provided the investigator with the name and composer or arranger for each piece. Data for each piece of music performed was recorded separately. Although the original intention was to have the participant only conduct full pieces of music and start and finish in the same neutral pose, it was quickly identified that this was not realistic. To reduce the amount of disruption during working rehearsals, data were recorded during segments of songs as well, with the investigator starting and stopping the recording as the participant started and stopped their conducting.

Following the performance protocol, the investigator aided the participant in safely removing the IMUs and answered any questions from members of the ensemble as time permitted.

### *3.4 Data Processing and Analysis*

#### 3.4.1 Outcome Variables

The outcome variables in this study include the mean, median, maximum, and minimum joint angles, the joint/segment range of motion, and the intra-participant variability for the joints/segments and rotations listed in Table 1. Percent time spent in neutral and non-neutral postures (based on thresholds derived from McAtamney and Corlett [1993] and Humadi et al. [2021]) were also analyzed. Outcome variables were calculated for each individual trial or sample, for the total time spent conducting for each participant, and for all participants together. The right and left sides of the body were examined separately for the wrist, elbow, and shoulder joints.

#### 3.4.2 Data Processing

Data were processed using MVN Analyze's built in biomechanical model, which allowed for real-time viewing of joint angle changes. Joint angles were processed and exported following ISB calculation recommendations (Schepers et al., 2018). Processing occurred in two phases. In real time, the data were analyzed frame-by-frame by the Xsens™ software, clearly identifying the position of each body segment. The data were then reprocessed after data collection was complete. This second processing occurred over a larger frame of time to obtain a more consistent and smooth calculation of each segment's position and location (Schepers et al., 2018). The reprocessed data were exported to Microsoft Excel (Redmond, WA, United States of America) for further analysis. Forearm pronation/supination was calculated by adding the elbow and wrist pronation/supination values together frame-by-frame (as per email communication with C. Broderick, Product Specialist Human Motion Measurement, Xsens, May 2021). Outlying points (for example if a participant dropped their music on the ground and stooped to pick it up) were removed as necessary before the outcome variables were calculated. These major outliers were identified by watching the video recording of the data collection session and making note of any outlying movement patterns, then locating the representative frames in the Excel files and removing them as necessary. As initial data analysis progressed, some clearly non-physiologic values (for example an elbow extension value of -180°, where zero degrees indicates full extension of the elbow and negative values indicate hyper-extension) were identified and removed from the dataset with relevant analyses re-calculated (as per email communication with C. Broderick, Product Specialist Human Motion Measurement, Xsens, May 2021). The number of frames deleted per participant ranged between 6 and 105 and represented 0.01-0.1% of the participant's available data.

### 3.4.3 Data Analysis

RULA and its associated posture bins were designed as a visual assessment tool, rather than one to be used with more precise and reliable data collected from motion capture systems. For this reason, and because of the small sample size, posture bins used to identify classifications for percent time calculations were simplified into three bins: neutral, above neutral, and below neutral. Similar to those used by Plantard et al. (2017) and Humadi et al. (2021), some of the neutral bin definitions used in conducting a RULA assessment were adjusted to account for the precision of the data collected by the motion capture system. The neutral range for wrist flexion/extension, wrist radial/ulnar deviation, and trunk flexion/extension was ± 5° (as opposed to 0°). RULA defines neutral elbow flexion as 60-100°, neutral shoulder flexion as ± 20°, and neutral neck flexion as 0-10°, relative to anatomical position. For all other ranges of motion of the upper body not previously defined, ± 20° relative to anatomical position was used to define a neutral range of motion (Plantard et al., 2017; Humadi et al., 2021). A summary of the joint posture classifications can be found below in Table 1. Pronation and supination of the forearm involves the addition of exported data from the wrist and the elbow, and this value will be included with the wrist joint/segment category.

**Table 1: A summary of the rotations examined and the joint/segment angle ranges corresponding to the neutral and non-neutral classifications for each joint.**

| Joint/Segment | Rotation | Classification | Angle Range |
|---|---|---|---|
| Shoulder | Flexion (+)/Extension (-) | Non-neutral (+) | > 20° |
| | | Neutral | ± 20° |
| | | Non-neutral (-) | < -20° |
| | Abduction (+)/Adduction (-) | Non-neutral (+) | > 20° |
| | | Neutral | ± 20° |
| | | Non-neutral (-) | < -20° |
| | Internal (+)/External (-) Rotation | Non-neutral (+) | > 20° |
| | | Neutral | ± 20° |
| | | Non-neutral (-) | < -20° |
| Elbow | Flexion (+)/Extension (-) | Non-neutral (+) | > 100° |
| | | Neutral | 60-100° |
| | | Non-neutral (-) | < 60° |
| Wrist | Flexion (+)/Extension (-) | Non-neutral (+) | > 5° |
| | | Neutral | ± 5° |
| | | Non-neutral (-) | < -5° |
| | Radial (+)/Ulnar (-) Deviation | Non-neutral (+) | > 5° |
| | | Neutral | ± 5° |
| | | Non-neutral (-) | < -5° |
| | Pronation (+)/Supination (-) | Non-neutral (+) | > 20° |
| | | Neutral | ± 20° |
| | | Non-neutral (-) | < -20° |
| Trunk | Flexion (+)/Extension (-) | Non-neutral (+) | > 5° |
| | | Neutral | ± 5° |
| | | Non-neutral (-) | < -5° |
| | Right (+)/Left (-) Lateral Bend | Non-neutral (+) | > 20° |
| | | Neutral | ± 20° |
| | | Non-neutral (-) | < -20° |
| | Right (+)/Left (-) Axial Rotation | Non-neutral (+) | > 20° |
| | | Neutral | ± 20° |
| | | Non-neutral (-) | < -20° |
| Neck | Flexion (+)/Extension (-) | Non-neutral (+) | > 10° |
| | | Neutral | 0-10° |
| | | Non-neutral (-) | < 0° |
| | Right (+)/Left (-) Lateral Bend | Non-neutral (+) | > 20° |
| | | Neutral | ± 20° |
| | | Non-neutral (-) | < -20° |
| | Right (+)/Left (-) Axial Rotation | Non-neutral (+) | > 20° |
| | | Neutral | ± 20° |
| | | Non-neutral (-) | < -20° |

### 3.4.4 Statistical Analysis

As expected, participants conducted with different movement patterns and habits in line with the genre of music being conducted and the level of experience of the conductor and the ensemble. For this reason, data were analyzed and presented both individually and in aggregate. As this study has more of an exploratory focus, descriptive statistics (as described in section 3.4.1 Outcome Variables) are highlighted. All statistical analyses were computed using Microsoft Excel (Redmond, WA, United States of America).

## *3.5 Study Significance*

The results of this study provide a foundation of knowledge in an area with otherwise limited research. It highlights the importance for future research on injury prevention in conductors and provides a starting point on which quantitatively supported recommendations can be made to reduce conductors' chances of developing WMSDs through their musical activities.

Participants and the ensembles with whom they work had the opportunity to experience a part of the research process first-hand. Participation in a project like this might have encouraged them to think about their movement patterns while conducting or performing, and in every-day life, and how it makes their bodies feel. The final results will provide participants with a better understanding of how their profession is viewed from a scientific point of view. Participants and their ensembles were also encouraged to think about how science and music can intertwine in education, research, and daily-life.

The scholarly community and other researchers will benefit from the results of this study as they can act as a proof-of-concept for further research in the area, drawing from a larger participant pool. As there is currently very little research already completed that investigates the kinematics of conducting within the context of injury prevention, the results of this study will provide an initial base of knowledge and may highlight other related areas that would benefit from further research. The number of participants in this study is too small to provide an accurate data set on which to form quantitative guidelines to help improve the profession, but it will encourage the research that will make projects like this possible in the future.

Health practitioners will also benefit from this research. Without really understanding the expectations placed on conductors and the movement patterns required for them to work in a professional capacity, health practitioners may find it especially challenging to treat or work with conductors as patients. The results of this study quantitatively describe the range of motion and repetitive nature of the job of a conductor, which may provide health care professionals with a greater understanding of the physical demands associated with conducting. As a result, these practitioners may be better able to help injured conductors return to their regular duties faster or help prevent healthy conductors from getting injured.

Finally, this study also acts as a pilot study to develop processes and procedures suitable to use motion capture data to answer research questions from social science and musical analysis perspectives. This will help us to better understand how the movement qualities of conducting gestures elicit different reactions from musical ensembles such as choirs.

# CHAPTER 4

# RESULTS

Seven conductors from Windsor-Essex and Chatham-Kent participated in this study. One participant self-identified their biological sex as female and six participants self-identified as male (mean height: 176.6 ± 5.1 cm, mean body mass 90.6 ± 17.0 kg). Their ages ranged from 33-69 years (mean: 59.1 ± 12.6 years) and they had an average of 32 ± 16.5 years of conducting experience. They conducted a variety of different styles of ensembles that include musicians with varying musical backgrounds. To protect the identities of the participants, they will be referred to as Conductors 1-7. Results will be reported for each participant individually in case study format with their cumulative results located in the body of the results section and individual trial/song results in Appendix E. Time histories of each joint/rotation for one representative trial per participant can also be found in Appendix F. Group results will be reported at the end of this chapter.

## *4.1 Conductor 1*

### 4.1.1 Intake Summary/Background

Conductor 1 was a right-handed 33-year-old female with approximately 1 year of conducting experience. She is a professional musician and music educator by day and holds a regular personal practice schedule on her primary instrument (voice), as well as secondary instruments (guitar and piano), which are primarily used to accompany her students. She has a doctoral degree in classical voice performance and has significant experience as a member of many different choirs where she received the opportunity to view and learn from numerous different styles of conductors. She did not describe participating in any hobbies that could result in relevant injuries. She has not had any injuries that have affected her conducting and spends approximately three hours per week conducting. She always uses a baton in performance, but sometimes finds herself using a pencil as a baton during rehearsal to make note taking easier. She is currently conducting a 35-person adult community choir that practices once per week. The choir is made up of community members who, although they are auditioned, are not required to (and many do not) read music or have any type of private musical training.

Conductor 1's community choir utilizes a community hall as a rehearsal space. The size of the room is not limiting, and the conductor has plenty of room to move the musicians around as necessary. Conductor 1 has complete control over her conducting setup, and she conducts from a lectern that is 125 cm high. During data collection, she was approximately 200 cm away from the closest musician.

During data collection, Conductor 1's ensemble rehearsed choral arrangements of the following songs:

- *Seasons of Love* (arr. Roger Emerson)
- *You Can't Stop the Beat* (arr. Roger Emerson)
- *You'll Never Walk Alone/Climb Every Mountain* (arr. Mark Hayes)
- *One Day More* (arr. Mark Brymer)
- *Don't Cry for me Argentina* (arr. Alan Billingsley)
- *Little Shop of Horrors* (arr. Mark Brymer)

### 4.1.2 Joint/Segment Angles and Calculations

Table 2 lists the cumulative mean, median, maximum, and minimum joint angles, as well as the range of motion and intrasubject variability for each joint and rotation throughout all analyzed data for Conductor 1. Data from the individual trials can be found in Appendix E.1 and related time-histories can be found in Appendix F.1.

Notable findings include the large percentage of time spent in wrist extension bilaterally (R: 99.8%; L: 71.8%), as well as approximately even distribution of time spent in non-neutral trunk flexion (17.4%), compared to non-neutral trunk extension (15.1%). Generally, with conducting, one upper extremity is responsible for the main conducting pattern while the other generally just provides extra cues. This was consistent with what Conductor 1 did during data collection, but they used both upper extremities almost equally, likely resulting in the similar wrist extension bilaterally (R: 99.8%; L: 71.8%). She mentioned that larger, more clear movement patterns were required when working with her choir as most members do not read the music. Also, Conductor 1 spent a fairly equivalent amount of time in non-neutral trunk flexion (17.4%) and extension (15.1%). Her musicians noted that she usually dances while she conducts and that she was "tamer than usual" during the data collection session. If she was more comfortable to dance during data collection, more movement outside of a neutral range of motion at the trunk may have been observed.

**Table 2: Conductor 1 Joint Angle Summary.**

| | | | Descriptive Statistics (°) | | | | | | Time spent in Joint Posture Bins (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Joint/ Segment** | **Rotation** | **Right/ Left** | **Mean** | **Median** | **Max** | **Min** | **ROM** | **ISV** | **Below Neutral** | **Neutral** | **Above Neutral** |
| Neck | F/E | | 4.4 | 5.8 | 38.2 | -40.8 | 78.9 | 10.0 | 8.0 | 64.3 | 27.7 |
| | RLB/LLB | | -0.9 | -0.7 | 18.4 | -26.9 | 45.3 | 4.4 | 0.1 | 99.9 | 0.0 |
| | RAR/LAR | | 6.1 | 6.2 | 61.1 | -43.6 | 104.6 | 9.7 | 1.2 | 94.2 | 4.5 |
| Shoulder | F/E | Right | 11.4 | 8.8 | 97.3 | -21.8 | 119.1 | 13.3 | 0.0 | 78.4 | 21.6 |
| | | Left | 12.0 | 9.2 | 102.9 | -28.0 | 130.9 | 17.6 | 0.5 | 73.2 | 26.3 |
| | ABD/ADD | Right | 24.4 | 23.2 | 63.9 | 6.9 | 56.0 | 7.7 | 0.0 | 31.7 | 68.3 |
| | | Left | 26.9 | 24.9 | 67.0 | 2.7 | 64.3 | 10.7 | 0.0 | 30.6 | 69.4 |
| | IR/ER | Right | -18.6 | -19.8 | 59.1 | -48.7 | 107.8 | 11.8 | 49.0 | 50.5 | 0.5 |
| | | Left | -9.7 | -10.9 | 61.5 | -43.6 | 105.1 | 13.6 | 22.4 | 74.1 | 3.5 |
| Elbow | F/E | Right | 88.4 | 89.7 | 145.4 | -5.3 | 150.7 | 18.7 | 7.7 | 67.6 | 24.7 |
| | | Left | 99.0 | 104.6 | 158.1 | -0.3 | 158.4 | 22.8 | 6.5 | 35.4 | 58.2 |
| Wrist | F/E | Right | -37.7 | -40.8 | 6.7 | -54.8 | 61.4 | 9.1 | 99.8 | 0.2 | 0.0 |
| | | Left | -11.6 | -17.6 | 62.3 | -47.4 | 109.7 | 19.4 | 71.8 | 8.7 | 19.6 |
| | RD/UD | Right | 3.7 | 4.3 | 15.2 | -22.5 | 37.6 | 4.4 | 4.5 | 52.2 | 43.3 |
| | | Left | -3.9 | -0.9 | 17.5 | -47.0 | 64.5 | 11.5 | 37.1 | 38.4 | 24.6 |
| | P/S | Right | 92.2 | 114.1 | 158.7 | -9.6 | 168.2 | 43.0 | 0.0 | 10.0 | 89.8 |
| | | Left | 74.8 | 96.2 | 151.3 | -16.4 | 167.7 | 44.3 | 0.0 | 22.7 | 77.4 |
| Trunk | F/E | | 0.4 | 0.1 | 28.2 | -20.4 | 48.6 | 5.4 | 15.1 | 67.5 | 17.4 |
| | RLB/LLB | | 1.0 | 1.3 | 19.4 | -17.0 | 36.4 | 4.4 | 0.0 | 100.0 | 0.0 |
| | RAR/LAR | | 1.7 | 1.7 | 11.4 | -13.1 | 24.4 | 3.3 | 0.0 | 100.0 | 0.0 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

## *4.2 Conductor 2*

### 4.2.1 Intake Summary/Background

Conductor 2 is a right-handed 63-year-old male with approximately 41 years of conducting experience. He is retired from the education sector (where he was an accomplished music educator before transitioning into a supervisory role) and is well-known in the local music scene as a performer and educator. He holds a regular personal practice schedule on his primary instrument (trumpet) as well as secondary instrument (piano). He has a Master of Education degree and a Bachelor of Music degree, where he studied conducting and learned as a student conductor with an ensemble. He also has extensive experience as a member of many different ensembles where he had considerable opportunities to view and learn from different styles of conductors. Conductor 2 stays active playing and refereeing hockey and has not had any injuries that have affected his conducting. He spends approximately seven hours per week conducting with his ensembles, as well as additional time preparing for rehearsals. He regularly uses a baton both in rehearsal and performance. He is currently conducting a 43-person auditioned student instrumental ensemble where most musicians are in their early twenties and have private training on their instruments through university music education.

Conductor 2's ensemble utilizes a room at a post-secondary institution that was specifically designed for large ensemble rehearsals. Although the room is large, the size of the ensemble limits how it can set up within the room. Conductor 2 has complete control over their conducting setup, and he conducts from a conductor's stand that is 85 cm high while standing on a podium with a height of 16 cm. During data collection, he was 175 cm away from the closest musician.

During data collection, Conductor 2's ensemble rehearsed instrumental arrangements of the following songs:

- *A Festive Overture* (Alfred Reed)
- *The Cowboys* (John Williams)

4.2.2 Joint/Segment Angles and Calculations

Table 3 lists the cumulative mean, median, maximum, and minimum joint angles as well as the range of motion, and intrasubject variability for each joint and rotation throughout all analyzed data for Conductor 2. Data from the individual trials can be found in Appendix E.2 and related time-histories can be found in Appendix F.2.

Noteworthy findings include the large percentage of time that was spent in non-neutral neck flexion (72.3%), non-neutral trunk extension (66.1%), and non-neutral radial deviation at the left (62.2%) and right wrists (79.1%). In reviewing the video footage recorded during data collection, it was clear that Conductor 2 spent a large amount of time in a forward neck posture looking down at his music while conducting which resulted in 72.3% of his time being spent in non-neutral neck flexion. The video footage does not support the data that shows that Conductor 2 spent 66.1% of his time in non-neutral trunk extension, so it is expected that he was not standing perfectly straight during calibration thus negatively skewing the trunk data. The neutral range for trunk flexion is limited to ±5° and Conductor 2's average joint angle is -6.8º (ISV 6.0º). He also spent a large amount of time in radial deviation bilaterally at the wrist, but as the average joint angle was only 10º on the left and 11º on the right, there was not consistent severe radial deviation present. However, he did rely on radial deviation regularly when cueing.

**Table 3: Conductor 2 Joint Angle Summary.**

| | | | Descriptive Statistics (°) | | | | | | Time spent in Joint Posture Bins (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Joint/ Segment** | **Rotation** | **Right/ Left** | **Mean** | **Median** | **Max** | **Min** | **ROM** | **ISV** | **Below Neutral** | **Neutral** | **Above Neutral** |
| Neck | F/E | | 17.5 | 21.2 | 42.3 | -12.5 | 54.9 | 11.2 | 0.1 | 27.6 | 72.3 |
| | RLB/LLB | | -0.1 | -0.1 | 25.0 | -16.7 | 41.7 | 3.8 | 0.0 | 100.0 | 0.0 |
| | RAR/LAR | | 8.4 | 7.9 | 48.0 | -51.1 | 99.2 | 13.3 | 3.6 | 81.2 | 15.2 |
| Shoulder | F/E | Right | 50.6 | 50.2 | 105.8 | -12.0 | 117.7 | 15.7 | 0.0 | 2.5 | 97.5 |
| | | Left | 32.4 | 32.7 | 109.9 | -11.4 | 121.3 | 20.9 | 0.0 | 30.0 | 70.0 |
| | ABD/ADD | Right | 26.9 | 27.2 | 69.3 | -16.0 | 85.2 | 8.2 | 0.0 | 16.2 | 83.9 |
| | | Left | 31.0 | 33.5 | 72.4 | 3.1 | 69.3 | 12.9 | 0.0 | 27.4 | 72.6 |
| | IR/ER | Right | 6.8 | 5.6 | 56.7 | -33.2 | 89.9 | 12.4 | 1.3 | 83.6 | 15.1 |
| | | Left | -7.8 | -9.1 | 58.6 | -45.9 | 104.5 | 13.7 | 20.2 | 76.9 | 3.0 |
| Elbow | F/E | Right | 59.9 | 60.5 | 156.5 | -6.6 | 163.2 | 21.7 | 49.0 | 49.6 | 2.4 |
| | | Left | 42.1 | 40.0 | 165.7 | -21.4 | 187.0 | 33.0 | 69.5 | 25.7 | 4.8 |
| Wrist | F/E | Right | -12.8 | -17.6 | 89.6 | -31.4 | 120.9 | 16.4 | 87.3 | 4.5 | 8.2 |
| | | Left | -4.7 | -6.8 | 70.3 | -27.4 | 97.7 | 11.9 | 56.5 | 33.0 | 10.5 |
| | RD/UD | Right | 11.0 | 11.7 | 43.9 | -39.0 | 82.9 | 8.7 | 4.3 | 16.6 | 79.1 |
| | | Left | 9.3 | 9.5 | 61.0 | -49.6 | 110.6 | 13.2 | 11.7 | 26.1 | 62.2 |
| | P/S | Right | 44.3 | 47.3 | 115.1 | -51.1 | 166.1 | 23.0 | 1.2 | 13.5 | 85.4 |
| | | Left | 68.6 | 74.0 | 146.6 | -72.6 | 219.3 | 38.3 | 1.0 | 11.6 | 87.3 |
| Trunk | F/E | | -6.8 | -7.2 | 20.9 | -30.6 | 51.5 | 6.0 | 66.1 | 28.9 | 4.0 |
| | RLB/LLB | | -5.6 | -5.3 | 6.3 | -28.0 | 34.3 | 4.2 | 0.4 | 99.6 | 0.0 |
| | RAR/LAR | | -2.1 | -1.9 | 23.6 | -17.6 | 41.1 | 3.2 | 0.0 | 100.0 | 0.0 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

### *4.3 Conductor 3*

4.3.1 Intake Summary/Background

Conductor 3 is a left-handed 59-year-old male with more than 20 years of conducting experience. By day, he is a technical program manager in the automotive industry. He does not hold a regular personal practice schedule on his primary instrument (voice) and considers his ensemble his current primary instrument. He has a music performance degree where he took a course in conducting. He also has significant experience as a member of many different ensembles where he had ample opportunity to observe and learn from many different styles of conductors. Conductor 3 has not had any injuries that have affected his conducting and did not describe any significant current hobbies that may interact with potential conducting-related injuries. He spends approximately three hours a week conducting with his ensemble. He does not use a baton in rehearsal or performance. He is currently conducting a 30-plus-person community vocal ensemble where most musicians are older adults, and most do not have private training on an instrument. Some of the musicians read music, but it is not a requirement to participate in this musical ensemble.

Conductor 3's ensemble utilizes a large community hall as a rehearsal space. The size of the room is not limiting, and the conductor has plenty of room to move the musicians around as he sees necessary. Conductor 3 has complete control over his conducting setup and maintains a flexible setup as he likes to move around and stand in different positions while conducting. He has access to a stage that is 41 cm high that he occasionally stands on while conducting, and sometimes uses a standard music stand that was 117 cm high during data collection to hold his music. During data collection, Conductor 3 was generally about 235 cm away from his closest musician, but he moved around a lot throughout the data collection session.

During data collection, Conductor 3's ensemble rehearsed choral arrangements of the following songs:

- *Old Cape Cod* (Patti Page)
- *Simple Melody* (Bing Crosby)
- *Hooked on a Feeling* (B.J. Thomas)
- *Alexander's Ragtime Band* (Irving Berlin)

<u>4.3.2 Joint/Segment Angles and Calculations</u>

Table 4 lists the cumulative mean, median, maximum, and minimum joint angles as well as the range of motion, and intrasubject variability for each joint and rotation throughout all analyzed data for Conductor 3. Data from the individual trials can be found in Appendix E.3 and related time-histories can be found in Appendix F.3.

Notable findings include the amount of time spent in a neutral range of motion for neck flexion/extension (75.2%), as well as the larger range of motion on the left side, specifically in flexion, at the shoulder (158.0°). Conductor 3 was unique compared to the other participants in that he spent most of his time conducting from memory and his previous knowledge of the music and moved around a lot instead of standing (more or less) in one spot. He was up and down off the stage and moving around to be closer to certain groups of musicians during certain songs which contributed to a larger range of motion in many directions of movement such as neck rotation (99.3º) and elbow flexion (R: 142.3º; L: 158.0º). Since he was conducting from memory for most of the data collection session, his neck was in a more neutral range of motion instead of flexed looking down at his music. Conductor 3 was also left-handed and relied on his left upper extremity more as he was conducting, compared to most other conductors who relied on their right side for their main conducting pattern.

**Table 4: Conductor 3 Joint Angle Summary.**

| | | | Descriptive Statistics (°) | | | | | | Time spent in Joint Posture Bins (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Joint/ Segment** | **Rotation** | **Right/ Left** | **Mean** | **Median** | **Max** | **Min** | **ROM** | **ISV** | **Below Neutral** | **Neutral** | **Above Neutral** |
| Neck | F/E | | -0.3 | -2.9 | 63.8 | -24.9 | 88.7 | 10.6 | 10.9 | 75.2 | 13.8 |
| | RLB/LLB | | 1.9 | 2.8 | 15.1 | -21.8 | 36.9 | 5.2 | 0.0 | 100.0 | 0.0 |
| | RAR/LAR | | 5.1 | 9.3 | 42.0 | -57.4 | 99.3 | 21.3 | 15.4 | 53.2 | 31.4 |
| Shoulder | F/E | Right | 18.0 | 11.0 | 104.5 | -37.8 | 142.3 | 22.4 | 0.8 | 61.9 | 37.4 |
| | | Left | 39.7 | 38.8 | 119.3 | -38.7 | 158.0 | 20.2 | 1.8 | 10.4 | 87.8 |
| | ABD/ADD | Right | 25.9 | 22.4 | 72.2 | -0.4 | 72.7 | 11.0 | 0.0 | 40.9 | 59.1 |
| | | Left | 27.5 | 27.4 | 71.2 | -10.6 | 81.8 | 11.6 | 0.0 | 26.1 | 74.0 |
| | IR/ER | Right | -1.7 | -6.7 | 66.9 | -51.0 | 117.9 | 17.8 | 10.6 | 76.6 | 12.8 |
| | | Left | 17.3 | 17.1 | 86.8 | -34.4 | 121.2 | 15.0 | 0.3 | 57.4 | 42.3 |
| Elbow | F/E | Right | 18.0 | 11.0 | 104.5 | -37.8 | 142.3 | 22.4 | 0.8 | 61.9 | 37.4 |
| | | Left | 39.7 | 38.8 | 119.3 | -38.7 | 158.0 | 20.2 | 1.8 | 10.4 | 87.8 |
| Wrist | F/E | Right | -8.4 | -7.5 | 31.9 | -46.1 | 78.1 | 8.4 | 69.5 | 26.1 | 4.5 |
| | | Left | -11.0 | -11.1 | 40.3 | 48.7 | 89.0 | 9.7 | 77.0 | 18.6 | 4.4 |
| | RD/UD | Right | -3.0 | -3.4 | 26.0 | -41.0 | 66.9 | 8.7 | 41.1 | 42.7 | 16.2 |
| | | Left | -2.4 | -1.9 | 18.5 | -37.9 | 56.4 | 7.7 | 35.7 | 47.0 | 17.3 |
| | P/S | Right | 72.5 | 80.4 | 145.9 | -28.2 | 174.0 | 30.7 | 0.0 | 8.3 | 91.6 |
| | | Left | 76.7 | 80.8 | 143.8 | -18.7 | 162.6 | 26.0 | 0.0 | 4.6 | 95.4 |
| Trunk | F/E | | -2.5 | -3.1 | 24.9 | -35.1 | 60.0 | 5.8 | 35.2 | 54.7 | 10.1 |
| | RLB/LLB | | 1.9 | 1.6 | 15.0 | -13.0 | 28.0 | 3.3 | 0.0 | 100.0 | 0.0 |
| | RAR/LAR | | -0.3 | -0.1 | 12.7 | -14.0 | 26.7 | 3.3 | 0.0 | 100.0 | 0.0 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

### ***4.4 Conductor 4***

4.4.1 Intake Summary/Background

Conductor 4 is a right-handed 69-year-old male with more than 50 years of conducting experience. He is retired from the education sector and is currently a private music teacher. He holds a regular personal practice schedule on his primary instrument (euphonium) and secondary instrument (organ). He holds a Bachelor of Music degree and served with a military reserve music band as Assistant Director. He has significant experience as a member of many different ensembles as well where he had the opportunity to watch and learn from numerous different styles of conductors. Conductor 4 leads a fairly active lifestyle with regular strength training and has not had any injuries that have affected his conducting. He did not describe regularly participating in any specific hobbies that may interact with his conducting. He spends approximately two hours a week conducting with his ensemble and does not use a baton in rehearsal or performance. He is currently conducting a 40-50 person community instrumental ensemble where the musicians range in age from 14-88 years, and all of them read music. Many have had private training for their instrument at some point in their life, but do not currently take private lessons.

Conductor 4's ensemble utilizes a large community hall as a rehearsal space. The size of the room is not limiting and the conductor has plenty of room to move the musicians around as he sees necessary. Conductor 4 has complete control over his conducting setup and conducts from a 31 cm high podium using a 132 cm high stand. During data collection, he was 270 cm away from the closest musician.

During data collection, conductor 4's ensemble rehearsed instrumental arrangements of the following songs:

- *Dr. Who Medley* (arr. Robert Buckley)
- *This is Me* (arr. Michael Brown)
- *Miss Saigon* (arr. Warren Barker)
- *Nostalgic* (Paul Murtha)
- *Rock, Roll, and Remember* (arr. Ted Ricketts)
- *Make a Moment Last Forever* (arr. Michael Brown)

4.4.2 Joint/Segment Angles and Calculations

Table 5 lists the cumulative mean, median, maximum, and minimum joint angles as well as the range of motion, and intrasubject variability for each joint and rotation throughout all analyzed data for conductor 4. Data from the individual trials can be found in Appendix E.4 and related time-histories can be found in Appendix F.4.

Notable findings include the amount of time spent in non-neutral ulnar deviation on the right side (49.8%), as well as the amount of time spent in non-neutral elbow extension on the left (69.5%). Conductor 4 was unique compared to the other instrumental conductors who participated in this project as he did not use a baton while conducting. This freed up both his hands to be slightly more expressive compared to the other participants, which may have played a role in the amount of wrist movement. When looking at the elbow movement on the left side, it is important to remember that the neutral range identified for the elbow is 60-100°, so although Conductor 4 spent about 69.5% of his time on the left side in non-neutral elbow extension, that included time in the range between the minimum identified of -8° and the lower bound of the neutral zone (60°). As the right hand was primarily used for the main conducting pattern, the left hand was primarily used to provide extra emphasis and cues (such as pointing at a group of musicians to remind them to play). This translated into more extension and reaching from the elbow on the left side.

**Table 5: Conductor 4 Joint Angle Summary.**

| | | | Descriptive Statistics (°) | | | | | | Time spent in Joint Posture Bins (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Joint/ Segment** | **Rotation** | **Right/ Left** | **Mean** | **Median** | **Max** | **Min** | **ROM** | **ISV** | **Below Neutral** | **Neutral** | **Above Neutral** |
| Neck | F/E | | 18.0 | 20.2 | 60.1 | -23.6 | 83.7 | 10.1 | 2.6 | 12.9 | 84.5 |
| | RLB/LLB | | -9.1 | -9.2 | 9.0 | -32.8 | 41.8 | 4.7 | 1.0 | 99.1 | 0.0 |
| | RAR/LAR | | 13.9 | 13.8 | 49.5 | -30.5 | 80.0 | 9.5 | 0.4 | 76.2 | 23.4 |
| Shoulder | F/E | Right | 50.5 | 50.4 | 127.6 | -12.0 | 139.6 | 16.4 | 0.0 | 3.0 | 97.1 |
| | | Left | 26.0 | 22.7 | 103.8 | -33.1 | 136.9 | 24.1 | 0.0 | 46.7 | 53.3 |
| | ABD/ADD | Right | 25.2 | 25.0 | 65.2 | -46.1 | 111.3 | 11.7 | 0.1 | 32.2 | 67.7 |
| | | Left | 24.2 | 20.2 | 77.6 | -8.3 | 85.9 | 13.3 | 0.0 | 49.6 | 50.4 |
| | IR/ER | Right | 19.3 | 18.8 | 72.5 | -32.3 | 104.8 | 12.6 | 0.1 | 54.0 | 45.9 |
| | | Left | 2.3 | 0.5 | 71.3 | -49.7 | 121.0 | 14.3 | 3.4 | 83.9 | 12.7 |
| Elbow | F/E | Right | 66.7 | 67.2 | 133.3 | -10.1 | 143.4 | 22.1 | 38.0 | 55.8 | 6.3 |
| | | Left | 43.1 | 33.5 | 149.7 | -7.9 | 157.6 | 32.9 | 69.5 | 23.7 | 6.8 |
| Wrist | F/E | Right | 0.2 | -1.7 | 37.7 | -30.7 | 68.5 | 10.8 | 36.5 | 32.6 | 30.9 |
| | | Left | -1.1 | -0.8 | 34.3 | -34.3 | 68.5 | 11.5 | 30.3 | 41.1 | 28.6 |
| | RD/UD | Right | -5.9 | -5.0 | 26.6 | -47.9 | 74.5 | 9.2 | 49.8 | 40.6 | 9.6 |
| | | Left | 0.7 | 1.0 | 36.6 | -46.4 | 83.1 | 10.3 | 24.8 | 42.6 | 32.6 |
| | P/S | Right | 56.2 | 59.2 | 137.7 | -29.7 | 167.4 | 26.0 | 0.2 | 10.2 | 89.7 |
| | | Left | 70.4 | 78.1 | 172.4 | -60.9 | 233.3 | 35.0 | 0.7 | 10.4 | 88.9 |
| Trunk | F/E | | 6.9 | 7.3 | 36.7 | -21.3 | 58.0 | 9.0 | 9.8 | 31.6 | 58.7 |
| | RLB/LLB | | 3.9 | 4.2 | 29.7 | -23.5 | 53.2 | 7.5 | 0.0 | 99.4 | 0.5 |
| | RAR/LAR | | 0.4 | 0.3 | 31.1 | -23.4 | 54.5 | 4.8 | 0.0 | 99.5 | 0.5 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

## *4.5 Conductor 5*

4.5.1 Intake Summary/Background

Conductor 5 is a right-handed 55-year-old male with 33 years of conducting experience. He is the music director and primary conductor of a professional musical ensemble and does not hold a regular personal practice schedule on his primary instrument (oboe). He has a Master of Music in Conducting and spends approximately 12 hours a week conducting during the regular season, with a significant amount of time preparing for conducting as well. Conductor 5 leads a regularly active lifestyle and has recovered from a significant respiratory infection within the last 12 months that affected his conducting, with shortness of breath leading him to sit while conducting. He returned to full conducting duties, conducting as he normally would more than 30 days before the data collection session took place. He uses a baton both in rehearsal and performance. Conductor 5 is currently conducting a 45-person professional instrumental ensemble where most musicians are in their 40s-50s, and all have extensive private training on their individual instruments.

Conductor 5's ensemble utilizes a professional performance stage as a rehearsal space. The size of the space is not limiting, and the musicians have a very specific way in which they are always seated based on which instrument they play and their hierarchy or position within their section or instrument group. Conductor 5 has complete control over his conducting setup and he has access to a podium to stand on when necessary. During data collection, Conductor 5 was working with a smaller portion of the ensemble (14 musicians) where he was approximately 162 cm away from the closest musician and he used a stand that was 79 cm tall and did not stand on a podium.

During data collection, Conductor 5's ensemble rehearsed instrumental arrangements of the following songs:

- *Nimrod from Enigma Variations* (Edward Elgar)
- *Theme from Batman* (Danny Elfman)
- *Hornpipe from Watermusic* (George Frideric Handel)

<u>4.5.2 Joint/Segment Angles and Calculations</u>

Table 6 lists the cumulative mean, median, maximum, and minimum joint angles as well as the range of motion, and intrasubject variability for each joint and rotation throughout all analyzed data for Conductor 5. Data from the individual trials can be found in Appendix E.5 and related time-histories can be found in Appendix F.5.

Noteworthy findings include the small amount of time spent in a neutral range of wrist flexion/extension bilaterally. Interestingly, Conductor 5 spent most of his time in non-neutral wrist flexion on the right side (99.7%) compared to non-neutral wrist extension on the left side (83.7%). It was also unique that he spent more time in non-neutral shoulder abduction on the left side (74.0%) compared to the right side (49.3%). As the only conductor to have participated in this research who works with a professional musical ensemble; when reviewing the recorded footage, Conductor 5 displayed the most unique and extensive movement patterns compared to the other research participants. Since the musicians in Conductor 5's ensemble were more experienced and were able to receive more of the direction from the written notes on their sheet music in front of them, Conductor 5 was able to focus more on providing artistic direction and adding “colour” to the music through his conducting pattern. This resulted in different movement patterns compared to what was seen with the other participants.

**Table 6: Conductor 5 Joint Angle Summary.**

| | | | Descriptive Statistics (°) | | | | | | Time spent in Joint Posture Bins (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Joint/ Segment** | **Rotation** | **Right/ Left** | **Mean** | **Median** | **Max** | **Min** | **ROM** | **ISV** | **Below Neutral** | **Neutral** | **Above Neutral** |
| Neck | F/E | | 28.8 | 33.2 | 61.2 | -14.6 | 75.8 | 13.5 | 1.0 | 11.5 | 87.5 |
| | RLB/LLB | | -3.1 | -3.6 | 20.2 | -35.6 | 55.8 | 5.9 | 0.2 | 99.8 | 0.0 |
| | RAR/LAR | | -6.7 | -7.0 | 43.5 | -52.1 | 95.7 | 17.2 | 22.0 | 70.6 | 7.4 |
| Shoulder | F/E | Right | 50.9 | 50.8 | 105.8 | -25.4 | 131.2 | 22.1 | 0.0 | 9.0 | 91.0 |
| | | Left | 35.2 | 31.9 | 103.6 | -28.8 | 132.5 | 23.5 | 0.0 | 28.4 | 71.6 |
| | ABD/ADD | Right | 19.8 | 19.8 | 56.2 | -22.2 | 78.4 | 9.8 | 0.0 | 50.7 | 49.3 |
| | | Left | 29.0 | 27.9 | 73.7 | -2.8 | 76.5 | 12.8 | 0.0 | 26.1 | 74.0 |
| | IR/ER | Right | 10.4 | 10.4 | 46.9 | -36.4 | 83.3 | 11.1 | 0.7 | 80.8 | 18.5 |
| | | Left | 1.8 | 0.2 | 53.8 | -59.6 | 113.3 | 18.1 | 11.8 | 71.1 | 17.2 |
| Elbow | F/E | Right | 62.1 | 60.2 | 136.1 | -5.0 | 141.1 | 23.7 | 49.6 | 42.8 | 7.5 |
| | | Left | 54.5 | 57.6 | 136.7 | -4.2 | 140.9 | 23.7 | 54.7 | 43.3 | 2.0 |
| Wrist | F/E | Right | 28.4 | 26.4 | 58.7 | -10.0 | 68.8 | 8.7 | 1.0 | 0.2 | 99.7 |
| | | Left | -18.7 | -20.5 | 64.0 | -57.6 | 121.7 | 14.9 | 83.7 | 8.8 | 7.6 |
| | RD/UD | Right | -7.0 | -7.3 | 19.5 | 23.0 | 42.5 | 6.8 | 62.5 | 33.6 | 4.0 |
| | | Left | 0.0 | 1.0 | 19.2 | -29.5 | 48.7 | 8.0 | 26.7 | 41.9 | 31.3 |
| | P/S | Right | 86.9 | 81.6 | 158.3 | 25.5 | 132.8 | 27.3 | 0.0 | 0.0 | 100.0 |
| | | Left | 77.8 | 69.9 | 186.7 | -8.8 | 195.5 | 36.3 | 0.0 | 3.0 | 97.0 |
| Trunk | F/E | | 9.8 | 7.7 | 45.1 | -9.5 | 54.6 | 9.4 | 0.6 | 35.8 | 63.6 |
| | RLB/LLB | | 2.8 | 3.0 | 23.2 | -19.7 | 43.0 | 6.3 | 0.0 | 99.9 | 0.1 |
| | RAR/LAR | | 2.4 | 2.2 | 26.7 | -20.3 | 47.0 | 5.2 | 0.0 | 99.4 | 0.6 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

### *4.6 Conductor 6*

#### 4.6.1 Intake Summary/Background

Conductor 6 is a right-handed 69-year-old male with more than 40 years of conducting experience. He is a retired lawyer and does not hold a regular personal practice schedule on his primary (keyboard) or secondary (trumpet) instruments. He took music appreciation courses during his education in law, but apart from private lessons he does not have formal education in music. Conductor 6 is an occasional golfer and has not had any recent injuries related to, or that affect his conducting, and he did not describe regularly participating in any other hobbies that may interact with his conducting. He spends four to six hours per week conducting his ensemble and uses a baton in rehearsal or performance. He is currently conducting a 32-person community instrumental ensemble where the musicians range in age from approximately 17-85 years, all of whom read music. Many have had private training for their instrument at some point in their life, but do not currently take private lessons. Membership in Conductor 6's ensemble is skill-based by audition. On the day of data collection, 19 musicians were present and although that represents lower attendance than usual, all the parts (or unique musical selections that combine to form one song) were adequately covered.

Conductor 6's ensemble has access to a private bandshell and indoor hall for rehearsals. The size of the room is not limiting and the musicians were all situated on risers so they had improved line of sight to the conductor. Conductor 6 has complete control over his conducting setup and conducts from a 19 cm high podium using a 123 cm high stand.

During data collection, Conductor 6's ensemble rehearsed instrumental arrangements of the following songs:

- *Sergeant Pepper and the Lonely Heart Band* (arr. Michael Sweeney)
- *Latin Gold* (arr. Paul Lavender)
- *Game of Thrones* (arr. Jay Bocook)
- *Jersey Boys* (arr. Michael Brown)
- *More Cowbell* (arr. Michael Brown)
- *They Went Thataway* (arr. Paul Jennings)
- *Sleigh Ride* (Leroy Anderson)
- *Guys and Dolls* (arr. Calvin Custer)
- *Rock and Roll Hall of Fame* (arr. Paul Jennings)
- *Clarinet Candy* (Leroy Anderson)
- *It had Better be Tonight* (arr. Michael Brown)
- *Shoutin' Liza Trombone* (arr. Robert E Foster)
- *Cha Cha for Band* (Glen Osser)
- *Big Band Cavalcade* (arr. Andy Clark)
- *Acclimations* (Ed Huckeby)

4.6.2 Joint/Segment Angles and Calculations

Table 7 lists the cumulative mean, median, maximum, and minimum joint angles as well as the range of motion, and intrasubject variability for each joint and rotation throughout all analyzed data for Conductor 6. Data from the individual trials can be found in Appendix E.6 and related time-histories can be found in Appendix F.6.

Notable findings include the amount of time spent in non-neutral abduction at the right shoulder (98.3%) as well as the difference in time spent in non-neutral flexion at the elbow between the right (5.5%) and the left (61.9%). Shoulder abduction brings the upper extremity away from the body and Conductor 6 spent almost all his time with his right upper extremity in this position. This allowed him to produce bigger movement patterns without his trunk getting in the way and allowed the movement patterns to easily be visible by all members of the ensemble. The difference between the amount of time spent in non-neutral elbow extension between the right and left sides was also unique. It is important to highlight that the neutral range of motion at the elbow is 60-100°, so Conductor 6 did not spend 61.9% of his time with his left elbow hyper-extended, or beyond straight (the minimum value was -3°, just beyond zero). There is a noticeable difference between the right and left sides at the elbow, and that is likely a result of the different tasks assigned to the right and left upper extremities when conducting. The right side is generally responsible for the main, repetitive movements when conducting such as keeping time (thus the elbow and shoulder would remain flexed with the elbow in a mainly neutral ROM).  However, Conductor 6 more often used his left side for extra cues and to bring emphasis to important instructions. These cues (such as pointing at the line of trumpets to remind them to play out while they are being featured) require larger, more prominent movements and more elbow extension.

**Table 7: Conductor 6 Joint Angle Summary.**

| | | | Descriptive Statistics (°) | | | | | | Time spent in Joint Posture Bins (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Joint** | **Rotation** | **Right/ Left** | **Mean** | **Median** | **Max** | **Min** | **ROM** | **ISV** | **Below Neutral** | **Neutral** | **Above Neutral** |
| Neck | F/E | | 26.5 | 27.3 | 57.4 | -9.6 | 66.9 | 8.5 | 1.2 | 4.1 | 94.8 |
| | RLB/LLB | | 1.0 | 1.3 | 21.0 | -22.4 | 43.4 | 6.2 | 0.0 | 100 | 0.0 |
| | RAR/LAR | | -1.2 | -1.6 | 51.1 | -48.0 | 99.1 | 8.6 | 1.4 | 97.6 | 1.1 |
| Shoulder | F/E | Right | 33.9 | 33.2 | 95.0 | -5.3 | 100.3 | 9.9 | 0.0 | 6.5 | 93.5 |
| | | Left | 16.8 | 12.0 | 118.7 | -40.4 | 159.0 | 18.3 | 0.0 | 60.9 | 39.1 |
| | ABD/ADD | Right | 31.6 | 30.8 | 82.2 | 2.5 | 79.7 | 6.6 | 0.0 | 1.7 | 98.3 |
| | | Left | 22.1 | 21.3 | 88.4 | -6.3 | 94.6 | 8.7 | 0.0 | 37.2 | 62.8 |
| | IR/ER | Right | 4.5 | 3.6 | 74.4 | -48.5 | 123.0 | 10.9 | 0.7 | 91.5 | 7.8 |
| | | Left | -9.0 | -14.7 | 79.2 | -82.1 | 161.3 | 19.8 | 35.9 | 53.9 | 10.2 |
| Elbow | F/E | Right | 79.7 | 78.6 | 145.0 | 22.6 | 122.4 | 13.8 | 5.5 | 87.3 | 7.2 |
| | | Left | 58.3 | 55.6 | 153.0 | -2.9 | 155.9 | 21.5 | 61.9 | 33.5 | 4.6 |
| Wrist | F/E | Right | -9.4 | -8.8 | 19.6 | -29.5 | 49.1 | 4.8 | 85 | 14.8 | 0.2 |
| | | Left | -9.5 | -9.4 | 25.5 | -34.4 | 59.9 | 7.0 | 75.8 | 21.3 | 2.8 |
| | RD/UD | Right | -1.6 | -1.8 | 20.1 | -24.6 | 44.7 | 4.9 | 26.1 | 64.4 | 9.6 |
| | | Left | 0.9 | -0.2 | 38.1 | -54.3 | 92.4 | 12.6 | 33.7 | 30.4 | 35.8 |
| | P/S | Right | 27.0 | 24.0 | 122.5 | -28.5 | 150.9 | 19.8 | 0.1 | 41.4 | 58.5 |
| | | Left | 63.4 | 69.6 | 135.2 | -89.0 | 224.2 | 33.4 | 4.0 | 4.6 | 91.4 |
| Trunk | F/E | | 0.6 | 0.5 | 28.4 | -21.9 | 50.4 | 4.4 | 9.2 | 78.6 | 12.2 |
| | RLB/LLB | | -2.8 | -2.8 | 9.0 | -18.2 | 27.2 | 3.0 | 0.0 | 100.0 | 0.0 |
| | RAR/LAR | | -0.3 | -0.2 | 16.7 | -14.1 | 30.9 | 2.7 | 0.00 | 100.0 | 0.0 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

## *4.7 Conductor 7*

### 4.7.1 Intake Summary/Background

Conductor 7 is a right-handed 66-year-old male with more than 39 years of conducting experience. He is retired from the education sector and currently holds a regular, but light personal practice schedule on his primary instrument (trumpet). He holds an undergraduate degree in Physical Education and leads a lightly active lifestyle with regular outdoor activities. He did not describe regularly participating in any hobbies that may directly impact his conducting injury risk. About two years ago, he injured his shoulder in an accident, but that injury no longer affects how he conducts and has not affected how he conducts for more than 30 days. He spends approximately 5 hours a week conducting with his ensembles and uses a baton in rehearsal and performance. He is currently conducting a 58-person community instrumental ensemble where the musicians range in age from 18-90+ years; they all read music. Many have had private training for their instrument at some point in their life and played their instrument throughout high school, but do not currently take private lessons.

Conductor 7's ensemble utilizes a large community hall as a rehearsal space. The size of the room is not limiting. Conductor 7 has complete control over his conducting setup and conducts from a 62 cm high stage using a 79 cm high custom-designed electronic music stand-tablet setup. During data collection, he was 150 cm away from the closest musician. He also uses a microphone to ensure all musicians, even those hard of hearing due to age, can hear him well.

During data collection, Conductor 7's ensemble rehearsed instrumental arrangements of the following songs:

- *Joseph and the Amazing Technicolour Dreamcoat* (arr. Michael Sweeney)
- *Great Themes from Great Italian Movies* (arr. John Cavacas)
- *Les Miserables Medle*y (arr. Warren Barker)
- *Phantom of the Opera Medley* (arr. Paul Lavender)

4.7.2 Joint/Segment Angles and Calculations

Table 8 lists the cumulative mean, median, maximum, and minimum joint angles as well as the range of motion, and intrasubject variability for each joint and rotation throughout all analyzed data for Conductor 7. Data from the individual trials can be found in Appendix E.7 and related time-histories can be found in Appendix F.7.

Notable findings include the difference in percent time spent in non-neutral radial deviation at the wrist between the right and left sides (81.9% vs. 14.6%, respectively) and the difference in the maximum values of axial rotation at the neck between left (minimum value) and right axial rotation (maximum value, -65.6° and 43.0°, respectively). At the wrist, it was expected that Conductor 7 would show more extreme values on his right-hand side as he mentioned that he was right-handed, and the main conducting pattern is usually completed with the right hand. However, upon reviewing the video recording of the data collection session, this participant spent a large portion of their time with their wrist rotated so there was a lot of movement visible not only in wrist extension (as has been seen with nearly all the participants), but also in radial deviation. Also, although the neck was in a neutral posture range for rotation for most of the time (95.1%), Conductor 7 relied on a larger range of motion to the left (65.6°) compared to the right (43.0°). This was likely due to the position of key musicians in the ensemble, such as soloists or instrumentalists playing key parts. Conductor 7 turned his neck further to the left to ensure he could clearly see them when he needed to provide them with an important cue. Similar to most conductors, Conductor 7 frequently looked down to reference their own sheet music as they were conducting. With 79.3% of their time spent in non-neutral neck flexion with an average angle of 16.2°, their neck flexion was more noticeable than some of the other participants previously discussed as they were continuously referencing their music.

**Table 8: Conductor 7 Joint Angle Summary.**

| | | | Descriptive Statistics (°) | | | | | | Time spent in Joint Posture Bins (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Joint** | **Rotation** | **Right/ Left** | **Mean** | **Median** | **Max** | **Min** | **ROM** | **ISV** | **Below Neutral** | **Neutral** | **Above Neutral** |
| Neck | F/E | | 16.2 | 18.6 | 42.2 | -23.9 | 66.1 | 10.4 | 9.8 | 10.9 | 79.3 |
| | RLB/LLB | | -1.2 | -0.9 | 17.6 | -20.0 | 37.5 | 4.3 | 0.0 | 100.0 | 0.0 |
| | RAR/LAR | | -1.1 | -1.7 | 43.0 | -65.6 | 108.6 | 10.3 | 2.9 | 95.1 | 2.0 |
| Shoulder | F/E | Right | 44.7 | 43.1 | 114.3 | -17.2 | 131.5 | 14.8 | 0.0 | 2.4 | 97.6 |
| | | Left | 27.2 | 23.2 | 97.0 | -40.9 | 138.0 | 20.5 | 0.2 | 44.0 | 55.8 |
| | ABD/ADD | Right | 25.0 | 22.9 | 79.5 | -21.3 | 100.8 | 11.5 | 0.0 | 37.2 | 62.8 |
| | | Left | 23.8 | 22.9 | 72.6 | -20.0 | 92.7 | 7.6 | 0.0 | 29.6 | 70.4 |
| | IR/ER | Right | 7.5 | 6.9 | 75.3 | -48.3 | 123.6 | 13.3 | 1.3 | 83.0 | 15.7 |
| | | Left | 8.5 | 6.6 | 63.4 | -40.6 | 104.0 | 15.4 | 1.0 | 76.5 | 22.4 |
| Elbow | F/E | Right | 68.2 | 66.1 | 134.1 | -11.8 | 145.9 | 22.6 | 39.2 | 51.0 | 9.8 |
| | | Left | 64.8 | 65.2 | 147.4 | -18.9 | 166.3 | 26.7 | 42.1 | 48.6 | 9.4 |
| Wrist | F/E | Right | -25.6 | -27.8 | 33.5 | -43.4 | 76.9 | 8.8 | 97.2 | 2.1 | 0.7 |
| | | Left | -12.0 | -12.4 | 26.4 | -40.5 | 66.8 | 8.2 | 77.5 | 21.2 | 1.4 |
| | RD/UD | Right | 12.6 | 13.8 | 33.3 | -41.5 | 74.8 | 9.6 | 4.8 | 13.3 | 81.9 |
| | | Left | -5.6 | -5.8 | 32.2 | -52.6 | 84.8 | 10.1 | 53.2 | 32.2 | 14.6 |
| | P/S | Right | 63.3 | 63.4 | 175.4 | -28.7 | 204.1 | 16.5 | 0.0 | 0.9 | 99.1 |
| | | Left | 72.1 | 72.1 | 162.6 | -45.3 | 207.9 | 28.0 | 0.6 | 2.4 | 97.0 |
| Trunk | F/E | | 0.1 | -0.4 | 25.8 | -13.1 | 38.9 | 4.2 | 7.6 | 81.7 | 10.7 |
| | RLB/LLB | | 1.2 | 1.5 | 12.4 | -14.2 | 26.6 | 3.1 | 0.0 | 100.0 | 0.0 |
| | RAR/LAR | | -0.8 | -0.8 | 7.3 | -21.6 | 28.9 | 2.1 | 0.0 | 100.0 | 0.0 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

### *4.8 Results Summary*

Table 9 lists the cumulative mean, median, maximum, and minimum joint angles as well as the range of motion, and intrasubject variability for each joint and range of motion throughout all analyzed data for all the participants together. To provide increased clarity – these values are calculated from all seven participants' data combined as if they were collected on a single participant. Therefore, these values do not represent the average of the individual participants' data. Conducting, and music in general, is such a variable activity, with each participant having their own individual style, which may vary based on many factors. Averaging the values, especially with a small sample size, would not respect this individual variability.

Notable results include the amount of time spent in outside of neutral postures, especially at the shoulder, wrist, and neck. More than 80% of the conductors' time was spent in non-neutral shoulder flexion on the right-hand side. Although this number is very high, it does match expectations, as most of the participants self-identified as being right-handed and all were observed completing their main conducting patterns with their right upper extremities held out in front of their bodies, which would require prolonged shoulder flexion. Also, the participants exhibited non-neutral wrist extension (73.5% and 64.0% on the right and left sides, respectively) at a much higher proportion than the percent time spent in non-neutral flexion (12.5% and 11.7% on the right and left sides, respectively). Extension is required at the wrist as the conductor clearly identifies the first or main beat of each bar of music, bringing attention to their neutral starting position and rarely entering flexion. Although the right upper extremity is generally responsible for the main conducting patterns, the conductors all used their left upper extremities as well to bring extra attention to their musical instructions and expand their standard conducting patterns so they would be visible to the whole ensemble. Finally, almost three quarters of the conductors' time (73.6%) was spent in non-neutral neck flexion. This value is in line with expectations, especially considering the neutral range for the neck is relatively small (0-10°), and given that the conductors frequently look down to reference their own sheet music.

**Table 9: Cumulative Joint Angle Summary – all participants.**

| | | | Descriptive Statistics (°) | | | | | | Time spent in Joint Posture Bins (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Joint** | **Rotation** | **Right/ Left** | **Mean** | **Median** | **Max** | **Min** | **ROM** | **ISV** | **Below Neutral** | **Neutral** | **Above Neutral** |
| Neck | F/E | | 19.5 | 21.9 | 63.8 | -35.4 | 99.2 | 12.4 | 11.8 | 14.6 | 73.6 |
| | RLB/LLB | | -2.3 | -1.9 | 25.0 | -35.5 | 60.5 | 6.7 | 0.2 | 99.7 | 0.0 |
| | RAR/LAR | | 4.0 | 3.6 | 51.4 | -65.6 | 117.0 | 13.3 | 3.3 | 86.7 | 10.0 |
| Shoulder | F/E | Right | 37.3 | 37.3 | 127.6 | -37.8 | 165.5 | 20.3 | 0.0 | 18.3 | 81.7 |
| | | Left | 23.3 | 20.1 | 119.3 | -40.9 | 160.2 | 22.1 | 0.2 | 49.7 | 50.1 |
| | ABD/ADD | Right | 26.8 | 27.0 | 82.2 | -46.1 | 128.3 | 10.0 | 0.0 | 23.9 | 76.0 |
| | | Left | 24.9 | 22.7 | 88.4 | -20.0 | 108.4 | 11.1 | 0.0 | 35.9 | 64.1 |
| | IR/ER | Right | 5.1 | 5.5 | 75.3 | -51.0 | 126.3 | 16.8 | 8.0 | 74.0 | 18.0 |
| | | Left | -1.7 | -3.3 | 86.8 | -82.1 | 168.9 | 18.4 | 16.8 | 69.8 | 13.4 |
| Elbow | F/E | Right | 72.8 | 74.5 | 156.5 | -17.6 | 174.2 | 22.9 | 26.0 | 63.9 | 10.0 |
| | | Left | 61.0 | 59.4 | 165.7 | -21.6 | 187.2 | 32.3 | 50.8 | 35.2 | 14.0 |
| Wrist | F/E | Right | -12.2 | -10.7 | 89.6 | -54.8 | 144.3 | 17.7 | 73.5 | 14.0 | 12.5 |
| | | Left | -8.3 | -8.9 | 70.3 | -57.6 | 127.9 | 12.5 | 64.0 | 24.3 | 11.7 |
| | RD/UD | Right | 1.1 | 0.6 | 43.9 | -47.9 | 91.8 | 10.1 | 25.8 | 42.8 | 31.3 |
| | | Left | -0.3 | -0.3 | 61.0 | -54.3 | 115.3 | 11.9 | 33.0 | 35.6 | 31.4 |
| | P/S | Right | 55.0 | 54.4 | 175.4 | -51.1 | 226.5 | 34.8 | 0.2 | 17.7 | 82.2 |
| | | Left | 69.8 | 74.7 | 186.7 | -89.0 | 275.7 | 35.2 | 1.5 | 8.6 | 89.9 |
| Trunk | F/E | | 1.7 | 0.6 | 45.1 | -35.1 | 80.2 | 7.8 | 15.9 | 59.5 | 24.6 |
| | RLB/LLB | | 0.0 | -0.5 | 29.7 | -28.0 | 57.7 | 5.9 | 0.0 | 99.8 | 0.1 |
| | RAR/LAR | | -0.2 | -0.3 | 31.1 | -23.4 | 54.5 | 3.7 | 0.0 | 99.8 | 0.1 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

### *4.9 Investigator's Measurement Evaluation – Reliability Results*

Prior to commencing data collection, a small sub-study was completed to determine the primary investigator's measurement reliability. Ten participants recruited from the student population of the Faculty of Human Kinetics over social media came to the lab where their anthropometric measurements were taken a total of three times. The measurements (as required by the MVN Analyze software to scale the biomechanical model) were each taken on the right side of the body (as appropriate) using the soft measuring tape that comes with the Xsens™ hardware. The order of the measurements was randomized with a unique list or order created for each participant. The measurements were completed in rotational order straight through the list from top to bottom three times. Reliability was calculated as the coefficient of variation by dividing the standard deviation by the mean for each measurement for each participant, then multiplying by 100 to obtain a percentage (Table 10). It was determined that the investigator completed the measurements as required by the MVN Analyze software with an overall coefficient of variation of 1.3 (±0.9)% with a range of 0.2% (body height) to 3.1% (hip width).

**Table 10: Measurement Reliability Calculations (coefficients of variation) by Participant and Measurement (%)**

| Participant / Measurement | M01 | M02 | M03 | M04 | M05 | M06 | M07 | M08 | M09 | M10 | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Body height | 0.3 | 0.6 | 0.2 | 0.0 | 0.0 | 0.3 | 0.3 | 0.0 | 0.3 | 0.0 | 0.2 |
| Shoulder height | 0.5 | 0.9 | 1.5 | 0.0 | 1.2 | 0.2 | 0.4 | 0.5 | 0.3 | 0.4 | 0.6 |
| Shoulder width | 1.1 | 5.0 | 0.9 | 0.7 | 1.7 | 1.1 | 0.8 | 1.2 | 1.1 | 0.0 | 1.4 |
| Elbow span | 0.6 | 2.6 | 1.2 | 1.8 | 0.3 | 0.3 | 0.8 | 0.6 | 0.6 | 0.6 | 1.0 |
| Wrist span | 0.1 | 1.5 | 2.3 | 0.8 | 1.1 | 1.3 | 0.4 | 0.4 | 0.3 | 0.4 | 0.9 |
| Arm span | 0.3 | 2.0 | 0.3 | 0.5 | 0.7 | 0.4 | 0.4 | 0.3 | 0.0 | 0.4 | 0.5 |
| Hip width | 1.6 | 5.6 | 2.7 | 2.5 | 4.8 | 6.9 | 1.4 | 1.7 | 1.9 | 2.1 | 3.1 |
| Hip height | 0.6 | 2.7 | 1.2 | 2.4 | 0.3 | 0.6 | 0.6 | 0.7 | 1.1 | 1.1 | 1.1 |
| Knee height | 1.0 | 2.5 | 2.6 | 1.2 | 1.3 | 2.6 | 1.1 | 1.8 | 0.8 | 0.3 | 1.5 |
| Ankle height | 4.9 | 4.3 | 2.6 | 0.0 | 0.0 | 7.2 | 2.6 | 2.7 | 0.0 | 2.5 | 2.7 |
| Foot length | 0.8 | 1.2 | 1.8 | 0.0 | 1.0 | 1.8 | 0.2 | 1.8 | 0.3 | 0.0 | 0.9 |

| | |
|---|---|
| **Overall Average:** | 1.3% |
| **Standard Deviation** | 0.9% |

# CHAPTER 5

# DISCUSSION

The purpose of this study was to investigate and describe the upper body movement patterns associated with conducting. When observing a conductor, it is clear that they make use of a large range of motion bilaterally in their upper limbs and are very repetitive with their movements, but to the best of the PI's knowledge, specific investigation into the kinematics of conductors' upper limbs has not yet been completed to date. WMSDs have been identified as a problem for conductors (Luger and Trouli, 2023; Geraldo and Fiorini, 2022) and investigations into the performance of other instruments, such as the drums (Flammia and Azar, 2021) and the piano (Monino et al., 2017), have identified the large range of motion and repetitive movements required in performance. Consequently, it may be assumed that conducting would follow a similar pattern. This study used a portable motion capture system to collect information on conductors' movement patterns as they worked with their regular ensembles in their normal practice environments.

## *5.1 Research Question 1*

*Would Conductors' Overall Movement Patterns be Identified as Neutral or Non-Neutral Based on RULA Posture Bins?*

Although measurement of the upper limb is generally considered more challenging when the complexity of the joints (shoulder, elbow, wrist) and their movements are considered (Rau et al., 2000), the Xsens™ allowed this information to be collected and the familiar posture bins used in the RULA provided a recognizable point of comparison. It is important to note that the RULA was designed to assess static or stationary positions as opposed to changing positions seen over a period of time (as with conducting), so although the posture bins provide a recognizable point of comparison, the research supporting the RULA does not largely consider the amount of time spent in neutral or non-neutral posture bins (McAramney and Corlett, 1993). When all participants' data were analyzed together, most joints/segments were found to spend more time in a non-neutral ROM than a neutral ROM, including neck flexion/extension, shoulder flexion/extension bilaterally, shoulder abduction/adduction bilaterally, left elbow flexion/extension, wrist flexion/extension bilaterally, wrist radial/ulnar deviation bilaterally, and wrist pronation/supination bilaterally.

### *5.2 Research Question 2*

*Which Joints in Conductors' Upper Bodies Produce the Most Dynamic Range of Motion?*

The largest ROMs when all participants' data were analyzed together were seen in pronation and supination at the wrist (Right: 226.5°, Left: 275.7°) followed by flexion and extension at the elbow (Right: 174.2°, Left: 187.2°). These values are consistent with the PI's expectations as wrist pronation and supination (especially in conjunction with circumduction) is required as a conductor for cutting off or signaling the end of a musical piece. This movement pattern often involves the conductor circling one or both of their wrists as they return to the ictus or starting point. This signals to the musicians that they need to stop playing/singing. A large ROM was also expected at the elbow. Although the majority of conducting occurs while the elbow is flexed to some extent, conductors often extend their forearms completely at the elbow as they are providing cues to their musicians. As the left upper limb often carries most of the cues, the results showing that about 51% of the time at the elbow was spent below (or further extended from) the neutral range, follow expectations. On the right side, which generally carries the main conducting pattern, it was expected that more time would be spent in flexion. The fact that approximately 64% of time was spent in a neutral ROM for the elbow (between 60-100°), supports these expectations.

All calculated joint ROM values exceeded the common ROMs identified for activities of daily living (ADLs; Gates et al., 2016; Namadri et al., 2012; Sardelli et al., 2011). This follows expectations, as the calculated values include all participants cumulatively. It also supports the idea that a dynamic ROM is used at all segments and joints in the upper body during successful conducting.

### *5.3 Repetition*

Although other studies have used various types of motion capture systems to quantify repetitive movements (Pogrzeba et al., 2019), the specific definition of the number of repetitions required for a movement pattern to be considered repetitive has yet to be defined. Previously defined as a significant factor in the workplace (Frevialds, 2018; Gallagher and Heberger, 2013) and in the musical performance sector (Beckett et al., 2015; Flammia and Azar, 2021; Hopper et al., 2017; Shan and Visentin, 2003), repetition was visible in this study in the form of the numerous peaks and valleys in the time series (Appendix F) of nearly every joint or segment angle. Based on the clarity of the time series trace, repetition was especially visible at the elbow and wrist in flexion and extension. For example, in Image F.1.12 in Appendix F, which features a time series of the right wrist flexion and extension for Conductor 1 during one of their songs, approximately 33 major peaks can be seen in the span of one minute. Each of these major peaks represent a large wrist movement, signifying the first or down beat of each 4-beat bar. This matches the approximately 132 bpm music being sung in the recording.

### *5.4 Limitations*

As with many exploratory studies, these results must be considered with a number of limitations in mind. The most obvious limitation is the small sample size and participant pool, but other limitations include the lack of generalizability, issues with calibration, and the necessity of working around a working rehearsal when collecting data. These limitations vary in significance, especially when considering the numerous ways in which these data could be used in the future. The most significant limitation would be issues with calibration, as it results in less accurate data, and the least significant limitation would be the need to collect data around a working rehearsal. When considering the current lack of research in this area, the overall effects of the presented limitations are significantly outweighed by the presence of an initial study looking at the upper limb movement patterns of conductors.

#### 5.4.1 Sample Size and Geographical Limitations

Time and financial constraints limited travel for data collection, so all participants were identified from the music communities in Windsor-Essex and Chatham-Kent. Although both counties have thriving music scenes, they each only host a small number of musical ensembles and conductors/potential participants. This limited the potential participant pool and thus the sample size. Even though the present study provided valuable information that contributes positively to the current literature, a limited sample size ensures that the resulting data set and analysis cannot be generalized to the entire population of conductors in Canada or North America. This reduces the effect of the analysis on the field of conducting. Since the data collections were completed during regular rehearsals at each conductor's normal rehearsal space, there are two processes that would have been necessary to significantly increase the sample size:

1. travelling across the Canada-US border, or more than a couple hours within Canada from the University, or
2. completing all the required paperwork and processes to collect data within the local high schools in their music classes.

5.4.2 Lack of Generalizability

All participants were asked to conduct music that their ensemble was currently working on (to reduce the amount of stopping and starting), and no two data collection sessions were the same. This made the experience unique for the researchers, but it also ensured that the resulting analysis was not generalizable to the entire population of conductors, and reduced the comparisons that could be made between conductors.

5.4.3 Collecting Data In-Field

One of the highlights of this project is that data collection was completed in-field. In-field collections ensured that the results were as representative as possible of the movement patterns conductors experience during their regular rehearsal sessions. However, the in-field collections also limited the number of tools that could be used to collect the data. Although the Xsens™ was a good fit for this project, there are other motion capture systems available that are more accurate and reliable. As data collection occurred during regular rehearsal sessions, the researchers had to adapt the procedures so that they maintained due respect and keep the impact on the flow of rehearsal to a minimum. One adaptation was that the researchers were generally unable to collect data from full songs as originally planned. It was unrealistic to ask participants to start and stop each of the recordings in the same standardized anatomical position. Camera angles (and in some cases the style of camera used) were limited by the location of electrical plugs, the space available working around the musicians in the ensemble, and professional contract requirements limiting the recording of sound.

#### 5.4.4 Calibration Limitations Affecting the Resulting Data

Analysis was largely completed after data collection was complete, so potential calibration limitations were identified after they may have been able to be remedied. Extra attention was paid to ensure that participants stood as still as possible during the calibration process, and the Xsens™ software identified all final calibration sessions as *Good* (the highest rating available). Later, it was identified that participants likely did not stand with their elbows fully extended during calibration, which affected the resulting data. As the calibration sessions were not video-recorded, it is not possible to accurately quantify or estimate this. The biomechanical model is calibrated with the understanding that the calibration pose has the elbows extended to an angle of zero degrees. A more natural stance with a slight bend at the elbow joints may have inflated the amount of extension the system was able to perceive. This could be remedied in the future by having multiple experienced researchers watching the calibration process from different angles and by allotting more time for calibration (perhaps even before musicians arrive) to ensure the process is not rushed.

### *5.5 Future Directions*

The present study has identified the need for more research related to WMSDs and the kinematics of conducting. Future studies could improve the general knowledge in the area by investigating the upper limb movement patterns of a much larger sample. Standardizing the music conducted during data collection and collecting more information from participants about their conducting health-related education, would also be beneficial. To benefit the conductors directly, effective knowledge translation respecting their lived experiences and using terminology that is comfortable and accessible to them, needs to be planned for when the research is complete.

### 5.5.1 Sample Size

A larger sample involving a variety of conductor styles may help to improve the generalizability of the results. Increasing the geographical location from which participants are recruited would not only increase the pool of potential participants but would also increase the chances that the participants have a wider variety of previous education and musical influences. Conductors in a specific geographical area may have been trained or influenced by the same or similar musicians, in terms of their training and style. This future direction is suggested both locally (for example collecting participants from all of Southern Ontario instead of just two counties) and nationally/internationally. Internationally trained and practicing conductors (especially from countries outside of North America) adopt different conducting styles based on their geographical region of origin/training, so the inclusion of conductors with various geographical backgrounds would be especially interesting.

### 5.5.2 Standardizing the Music Conducted

Standardizing the music conducted, or having each participant conduct their ensemble through the same pieces of music on top of the music they would generally play, would also increase the comparisons that could be drawn between participants.

Standardizing the music conducted would ensure that the expected results (e.g., the beat patterns and expected dynamics) were the same between participants. This would help clarify the differences in movement patterns between participants. It would significantly complicate data collection procedures because conductors and their ensembles would need to receive the music far enough in advance so that they could learn the music.

### 5.5.3 Collecting Lower Body Data

The present study focused on the upper body movement patterns associated with conducting, given the association between upper body movement and musculoskeletal injury. Future research should consider documenting how conductors interact with the ground and move their lower body (e.g., bending knees) to support their upper body movements.

### 5.5.4 Increasing the Breadth of the Initial Interview Questions

The set of questions that was asked of the participants was designed to learn more about their conducting history and experience with previous injuries. Increasing the breadth of the questionnaire by asking participants about their previous education specifically related to WMSDs and injury prevention, would allow the results to be stratified based on educational background. Some conductors receive education on injury prevention when studying conducting (both formally and informally) or train with specific programs like the *Alexander Technique*, but that education may or may not be effective in preventing future injuries and ensuring the conductor develops habits that are healthy and sustainable long-term.

5.5.5 The Development of Effective Training Programs for Injury Prevention in Conductors

A clear extension of this research would be to develop an effective training program or set of lessons that address the main results. Generally, it must be stressed in all training for conductors that they should always consider how important their movement patterns are to their long-term conducting health. Identifying the aspects of conducting that are closely related to the development of WMSDs through the further expansion of the current research, will help conductors prevent possible issues throughout their careers. Components of training should include the types of movement studies and coaching already gaining popularity in the music world.

5.5.6 The Use of this Methodology Beyond Biomechanics and WMSDs

The current study was initially designed as a pilot project for future evaluations of conductors from a social science perspective (e.g., analyzing how a musical ensemble responds to different conductors). Datasets such as what was established herein could be used to further understand the movement patterns associated with conducting. The Xsens™ system was used effectively to document the movement patterns of conductors in music performance settings. Sufficient time needs to be provided for the setup and calibration of the system, and an appropriate number of researchers need to be present to ensure the participants stand perfectly still while the system is being calibrated. More video recording (from different angles and throughout the calibration process) would also provide investigators with more detailed information to identify abnormalities and make connections with the kinematic data.

# CHAPTER 6

# CONCLUSIONS

The results of this study can be summarized as follows:

- Supported by the guiding research question *What does the upper body movement patterns of a conductor look like?* this study set out to collect in-field data using a portable motion capture system to create a descriptive analysis of the upper body kinematics of conductors. To the best knowledge of the author, this study is the first to complete this objective.
- This study has examined the factors which are thought to contribute to the development of WMSDs in standard workplaces, non-neutral postures and repetition, and they are indeed also present in the required movement patterns for conducting. Before this study the presence of these factors in conducting were purely anecdotal.
- Using adapted RULA posture bins, this study identifies the movement patterns associated with conducting to be non-neutral especially in flexion and extension at the neck, shoulder, and wrist where a notable percentage of time was spent in the non-neutral category (85.4%, 81.7%, and 86.0% respectively).
- Upon visual inspection of time series graphs (Appendix F), repetition is clearly present in all joint and segment rotations analyzed. Visible in the numerous peaks and valleys present in the graphs, the amount of repetition varies based on the style of the conductor and the tempo (i.e. speed) of the music being conducted.

- These findings contribute in several ways to our understanding of the upper body kinematics of conductors and provide a basis for the importance of further research in the area.
- Future directions include continuing this research with a significantly larger sample size so generalizations and comparisons between different styles of conducting can be made. Effective knowledge translation will ensure the people most at risk from conducting WMSDs will be able to benefit from the research findings.

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# APPENDICES

## Appendix A: Letter of Informed Consent

University of Windsor

### CONSENT TO PARTICIPATE IN RESEARCH

Title of Study: ***A Descriptive Analysis of the Upper Body Movement Patterns of Conductors***

You are asked to participate in a research study conducted by **Jessica Flammia (graduate student) and Dr. Nadia Azar (faculty)**, from the **Department of Kinesiology** at the University of Windsor. **The results will contribute to Jessica's Master of Human Kinetics thesis research project.**

If you have any questions or concerns about the research, please feel to contact:

| | | |
|---|---|---|
| Jessica Flammia, primary investigator: | flammia@uwindsor.ca | |
| Dr. Nadia Azar, faculty supervisor: | azar5@uwindsor.ca | 519-253-3000 ext. 2473 |
| Dr. Dave Andrews, faculty supervisor: | dandrews@uwindsor.ca | 519-253-3000 ext. 2433 |

### PURPOSE OF THE STUDY

The goal of this study is to describe the movement patterns exhibited by experienced conductors throughout a series of songs. Specifically, this study will examine the movements at the trunk, neck, shoulder, elbow, and wrist joints within each song and across all songs. These data will provide a starting base of information to help others make research-based suggestions for improvements on conducting posture, practice, technique, and education while highlighting the need for future research.

### PROCEDURES

If you volunteer to participate in this study, you will be asked to:

**Prior to Meeting the Investigators:**

- contact Jessica through email to ensure you fall within the inclusion/exclusion criteria
- notify Jessica of your chosen songs to conduct and select mutually-convenient interview and data collection time slots
- send your ensemble members (and the parents/guardians of any members who are under the age of 18 years) a letter/email explaining that data collection will occur during one of your practice sessions (the date/time of data collection will be included in the letter). This letter/email will be provided by the research team.
- contact Jessica (flammia@uwindsor.ca) should you have any additional questions

**On the Day of your Interview:**

- meet with the investigator(s) over the phone or in a secure Microsoft Teams virtual meeting room

- complete a short intake interview including questions about your conducting experience and training, injury history, other hobbies related to the body positions required when conducting, demographics, and information about your musical ensemble such as size and level of experience.
- It is estimated that this interview should take less than 30 minutes

**On the Day of your Data Collection:**

- meet the investigator(s) at your regular practice or performance location wearing comfortable clothing and flat-soled shoes
- bring the baton and hearing protection you normally use (if any)
- introduce the investigator(s) to your ensemble
- be instrumented with the Xsens™ motion tracking system (sensors placed in specific positions on your arms, torso, and head using Velcro straps, gloves, a headband, and a fitted Lycra shirt)
- wear a 3-ply surgical mask during times when physical distancing cannot be maintained during data collection. These will be provided to you unless you prefer to use your own.
- complete the Xsens™ calibration process, which involves a brief period standing in a neutral pose, then walking back and forth a couple meters and a brief period of handclapping
- complete a brief (10 minute or less) warm up period to ensure you are comfortable with the data collection equipment
- conduct your ensemble through a set of performance-ready music between 15 and 30 minutes long with approximately 1 minute of rest in between songs.
- give your consent to the research team to take still photos and/or video recordings (including audio) before, during, and/or after the data collection.

**You will also be asked to:**

- consent to the publication of the motion capture data and photos/videos in any, or all, of several forums. Examples include, but are not limited to:
    - Summary on the University of Windsor's Research Results website
    - Conference or other academic presentations (e.g., teaching, guest lectures, speaking engagements, etc.)
    - Academic publications (e.g., master's thesis document, peer-reviewed journals)
    - Online (e.g., investigator's website, online music communities, blogs and/or vlogs)
    - Summaries and/or case studies shared through social media (e.g., Facebook, Twitter, Instagram, etc.)
    - Articles in popular music or conducting education magazines
    - Media appearances (e.g., radio, television, or online interviews such as podcasts, vlogs, and/or blogs)
    - Drummer Mechanics and Ergonomics Research Laboratory (DRUMMER Lab) promotional purposes (e.g., future study recruitment initiatives)

Publication in these forums can be achieved confidentially, if you wish. In those cases, no identifying information will be disclosed, and your face will be covered in any photos/videos (or, your photos/videos won't be used). **Please refer to the audio/video/still photography consent later in this document to indicate your desired level of confidentiality.**

It is estimated that the in-person data collection process will take 2-2.5 hours.

## INCLUSION AND EXCLUSION CRITERIA

You ***can*** participate in this study if:

- You are 18 years of age or older
- You are free from any kind of upper body injuries in the past 30 days that impacted your ability to conduct your ensemble to the skill and intensity levels to which you are accustomed.
    - If you have sustained such an injury/ailment within the last 12 months, you are eligible to participate if you have returned to your pre-injury/ailment conducting skill and intensity levels for at least 30 days.
- You have professional training in conducting such as a university music degree or professional mentorship
- You conduct a group of musicians at least once weekly, for at least two hours (total) each week while in your regular practice season.
- You work regularly with the same group of musicians in a practice setting where the research team can attend to complete data collection
- Your only role in the ensemble is that of conductor (e.g., you do not also regularly serve as accompanist, do not play another instrument or sing within the ensemble, etc.)

You ***cannot*** participate in this study if:

- You are younger than 18 years of age
- You are currently injured or have suffered any injury/ailments that affected your ability to conduct your ensemble to your accustomed level of proficiency and/or intensity within the last 30 days.
- You have suffered any injuries/ailments within the last 12 months and have not yet returned to your pre-injury/ailment conducting skill and intensity levels.
- You do not have sufficient professional or volunteer experience as a conductor
- You do not work with a group of musicians at least once a week for at least two hours each week during the regular practice season in a setting where the research team can safely complete the data collection process
- You are allergic to the adhesives used during data collection
- You are regularly serving the ensemble in another role besides being the conductor (e.g., accompanist)
- You are unable/unwilling to wear a face mask during times when physical distancing cannot be maintained during data collection

## POTENTIAL RISKS AND DISCOMFORTS

- The Velcro straps securing the sensors may chafe or irritate the skin, or may become uncomfortable if they are secured too tightly. Care will be taken to secure the Velcro straps in such a way that the adhesive surfaces do not touch the skin. You will be encouraged to let the investigators know if the Velcro straps are too tight or uncomfortable, so the straps can be adjusted.
- The t-shirt required as a part of the motion tracking system is made of Lycra, which may increase your body temperature more so than if you were conducting in a regular cotton or dry-fit t-shirt. You should let the investigators know if you need a break to cool down. You can also choose to withdraw from the study if you do not wish to continue.
- As an alternative to the Lycra t-shirt, medical-grade adhesive tape may be used to attach up to 3 sensors directly to your skin (underneath your own shirt). The adhesive tape may cause irritation to your skin. This irritation is similar to that which may develop from the use of commercially available bandages and is expected to disappear within a few days. You can choose to withdraw from the study if you do not wish to continue.
- Due to the nature of music performance, the volume in the data collection room will increase when your ensemble is performing. You are encouraged to bring your own hearing protection if you choose to use it.
- You may feel uncomfortable having your anthropometric measurements, height, or weight taken. This information is required by the motion tracking system to create an accurate biomechanical model. This information will remain confidential. You can also choose to withdraw from the study if you are not comfortable with having these measurements taken.
- You may feel uncomfortable while donning or removing the Lycra t-shirt, when sensors are being applied directly to the skin, or with the physical contact required during the anthropometric measurements and the application of the sensors and the Velcro straps. You can request that the investigators leave the data collection room while donning/removing the Lycra shirt. If you are

uncomfortable with the application of the Velcro straps by Jessica or a member of her team, you will be shown how to apply the straps yourself then they will be adjusted as necessary by Jessica or a member of her team when the sensors are applied. If adhesive tape must be used to secure the sensors to your back and chest, and you are uncomfortable with the physical contact that will be required for the investigators to do so, you may with draw from the study.

- You may feel uncomfortable disclosing the demographic information that is requested. This information is required to ensure the validity of the study and to ensure you meet all inclusion criteria. This information will remain confidential. If you do not want to disclose this information you can choose to withdraw from the study.
- If you have a prior relationship with anyone on the research team, you may feel uncomfortable completing any part of the research and data collection listed above with them present. The research team is attending in a professional capacity, but you can request that a different member of the research team conduct any portions of the study that you are uncomfortable completing with the person with whom you have a prior relationship. You can also choose to withdraw from the study at any point if you do not wish to continue.
- Although the data collection will occur in your regular practice space where you can control the privacy, it will occur with your ensemble present. Since data collection is being completed outside of the standard laboratory environment, the investigators cannot guarantee privacy. Your ensemble members may choose to discuss the research procedures with their friends or family, thus disclosing your participation. Also, the music community in the study area is small and close-knit, so there is the possibility that your colleagues may learn of your participation without you directly sharing that information. While we will take all possible steps to protect your confidentiality, there may be circumstances (such as those listed above) that are beyond our control. If you are concerned about the possible loss of status, privacy, and/or reputation you can choose to withdraw from the study.
- COVID-19 is still present in our community. You may feel anxious or concerned about potential exposure to COVID-19 from your participation in this study. Research staff will follow the University of Windsor's campus safety precautions, such as wearing 3-ply surgical masks during times when physical distancing cannot be maintained, to reduce the chance of possible disease transmission. Your participation in this study is completely voluntary, and you are free to withdraw from the study at any time by following the procedures outlined below.

## POTENTIAL BENEFITS TO PARTICIPANTS AND/OR TO SOCIETY

While we do not anticipate any direct benefits to participants, you might benefit from knowing that you contributed to research in an otherwise lacking field and, being a conductor yourself, one in which you have a vested interest. By participating in this study, you might begin to pay more attention to your posture when you conduct in the future. Due to the large gap in the research on the kinematics and biomechanics of conductors, this research will help highlight the need for future research upon which recommendations for conductor posture, practice habits, technique, education etc., may be based. It will also help foster a relationship between the Department of Kinesiology and School of Creative Arts that will be built upon in the future. This study will act as a pilot study to develop processes and procedures suitable to use motion capture data to answer research questions from social science and musical analysis perspectives, such as to better understand how the movement qualities of conducting gestures elicit different reactions from musical ensembles such as choirs.

## COMPENSATION FOR PARTICIPATION

You will receive a Kinesiology Research t-shirt as a token of gratitude for your time

## CONFIDENTIALITY

Participant anonymity is not possible with this research as the data collection is required to occur in person, with you, your musical ensemble, and the investigators and occasionally other members of the research team (i.e., other lab members who are there for training or to provide assistance) in the same room. Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission. Given that the population of conductors in the regions from which participants will be recruited is small and closely knit, it is possible that you may be identifiable in publications or presentations even when steps are taken to preserve participant confidentiality. Furthermore, the investigator will not be able to control what is shared by your ensemble members.

Data confidentiality will be handled as follows:

1. Information collected during the initial interview and the motion capture data will be collected and stored in a de-identified manner (i.e., by participant code only). These data will also be disseminated in a de-identified manner unless you indicate that you consent to non-confidential dissemination on the last page of this informed consent form (i.e., the audio/video/still photography consent form).
2. All audio-visual files will be collected and stored in a de-identified manner (i.e., by participant code only). Video/photos will only be used for dissemination if you indicate your consent for partially confidential or non-confidential use of your photos/videos on a subsequent page of this informed consent form. Although these files will be de-identified in naming convention (i.e., labelled with your participant code and not your first/last name) it will not be possible to remove your identifying features (e.g., your face, unique tattoos).
3. A file linking participant names to their participant codes will be encrypted, password protected, and stored on the investigators' password-protected computers and/or OneDrives.

Raw data are valuable for future studies, and therefore the data collected in this study will not be destroyed. Hard copies of the signed informed consent forms and the de-identified intake forms will be kept in a locked filing cabinet in the Biomechanics Lab and will be labelled with individualized participant codes until the conclusion of the study, when they will be moved to a locked filing cabinet in the faculty supervisor's office and stored indefinitely. The photos/videos and the de-identified digital data will be stored indefinitely on the investigators' password-protected computers and/or OneDrive. All data recorded will be labelled with the participants' unique identifying code and not their name. A document linking participants' names and unique identifying codes will be encrypted, password protected, and kept on the investigators' password-protected computers and/or OneDrives. At the end of the study, Jessica will surrender this file to Dr. Azar and will delete it from his computer. However, she will retain the right to keep an encrypted copy of the photos/videos and the de-identified data. Dr. Azar will keep the file linking participant names to their codes indefinitely (i.e., in an encrypted, password-protected file and kept on a password-protected computer and/or OneDrive). The GlobalProtect Virtual Private Network (VPN) will be used on all computers that are used to access the data.

## PARTICIPATION AND WITHDRAWAL

You will be able to withdraw from the study at any point up until **two weeks** following the completion of your in-person data collection. Beyond this date, data analysis will be underway and we will not be able to remove your data from the set.

You may withdraw verbally during the data collection or in writing before or after the data collection by contacting Jessica (flammia@uwindsor.ca). If you choose to withdraw from participation during the data collection period, the study will be stopped immediately. As soon as you withdraw from participation (either verbally or in writing within 2 weeks of your data collection date) your digital data will be promptly deleted from all electronic devices and databases and hard copies will be destroyed. The investigator may withdraw you from this research if circumstances arise which warrant doing so. These circumstances may include, but are not limited to, the determination that you do not fall within the inclusion criteria.

All participants who schedule and show up to their assigned data collection time slot will receive and be welcome to keep a Kinesiology Research t-shirt as our token of gratitude for their time.

## FEEDBACK OF THE RESULTS OF THIS STUDY TO THE PARTICIPANTS

A summary of the findings of this research will be made available to participants and the general public upon completion. It will be posted on the University of Windsor's research results website (address below) as well as on the faculty supervisor's social media.

Web address: https://scholar.uwindsor.ca/research-result-summaries/

Social media handle: @DrNadiaAzar (Facebook, Instagram, Twitter)
Date when results are available: May 24th, 2024

## SUBSEQUENT USE OF DATA

These data may be used in subsequent studies, in publications and in presentations.

## CONSENT FOR STILL PHOTOGRAPHY AND AUDIO/VIDEO RECORDING

This study will involve the use of still photography, video, and/or audio recording. These are voluntary procedures you are free to withdraw from at any time by requesting that the recording and/or photography be discontinued.

All recordings and photographs will be stored on password-protected computers and OneDrives. The GlobalProtect Virtual Private Network (VPN) will be used on all computers that are used to access the recordings/photographs.

These recordings/photographs may be used for dissemination of the results of the study in any, or all, of several forums. Examples include, but are not limited to:

- Summary on the University of Windsor's Research Ethics Board website
- Conference or other academic presentations (e.g., teaching, guest lectures, speaking engagements, etc.)
- Academic publications (e.g., master's thesis document, peer-reviewed journals)
- Online (e.g., investigator's website, online music communities, blogs and/or vlogs)
- Summaries and/or case studies shared through social media (e.g., Facebook, Twitter, Instagram, etc.)
- Articles in popular music or conducting education magazines
- Media appearances (e.g., radio, television, or online interviews such as podcasts, vlogs, and/or blogs)
- Drummer Mechanics and Ergonomics Research Laboratory (DRUMMER Lab) promotional purposes (e.g., future study recruitment initiatives)

I have indicated my level of consent to the use of audio/videotaping and/or photography of study procedures while wearing the research equipment, using the check boxes below:

☐ **Non-confidential use**: I give the investigators permission to use my likeness in the manners listed above without any masking, such that I will be fully identifiable in the photos/videos.

☐ **Partially confidential use**: I give the investigators permission to use my likeness in the manners listed above, provided that my face is masked. I understand that any visible tattoos or other markings may not be able to be masked, and so I may still be identifiable based on these features.

☐ **Fully confidential use only**: my videos and/or photos may only be viewed by the research team during data analyses. I do not wish for them to be used in any public presentations of the data.

## RIGHTS OF RESEARCH PARTICIPANTS

If you have questions regarding your rights as a research participant, contact: Research Ethics Coordinator, University of Windsor, Windsor, Ontario, N9B 3P4; Telephone: 519-253-3000, ext. 3948; e-mail: ethics@uwindsor.ca

## SIGNATURE OF RESEARCH PARTICIPANT/LEGAL REPRESENTATIVE

I understand the information provided for the study ***A Descriptive Analysis of the Upper Body Movement Patterns of Conductors*** as described herein. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

I confirm that I have shared the letter/email with the study information with all ensemble members and the parents/legal guardians of any ensemble members under the age of 18.

______________________________________

Name of Participant

______________________________________ ___________________

Signature of Participant Date

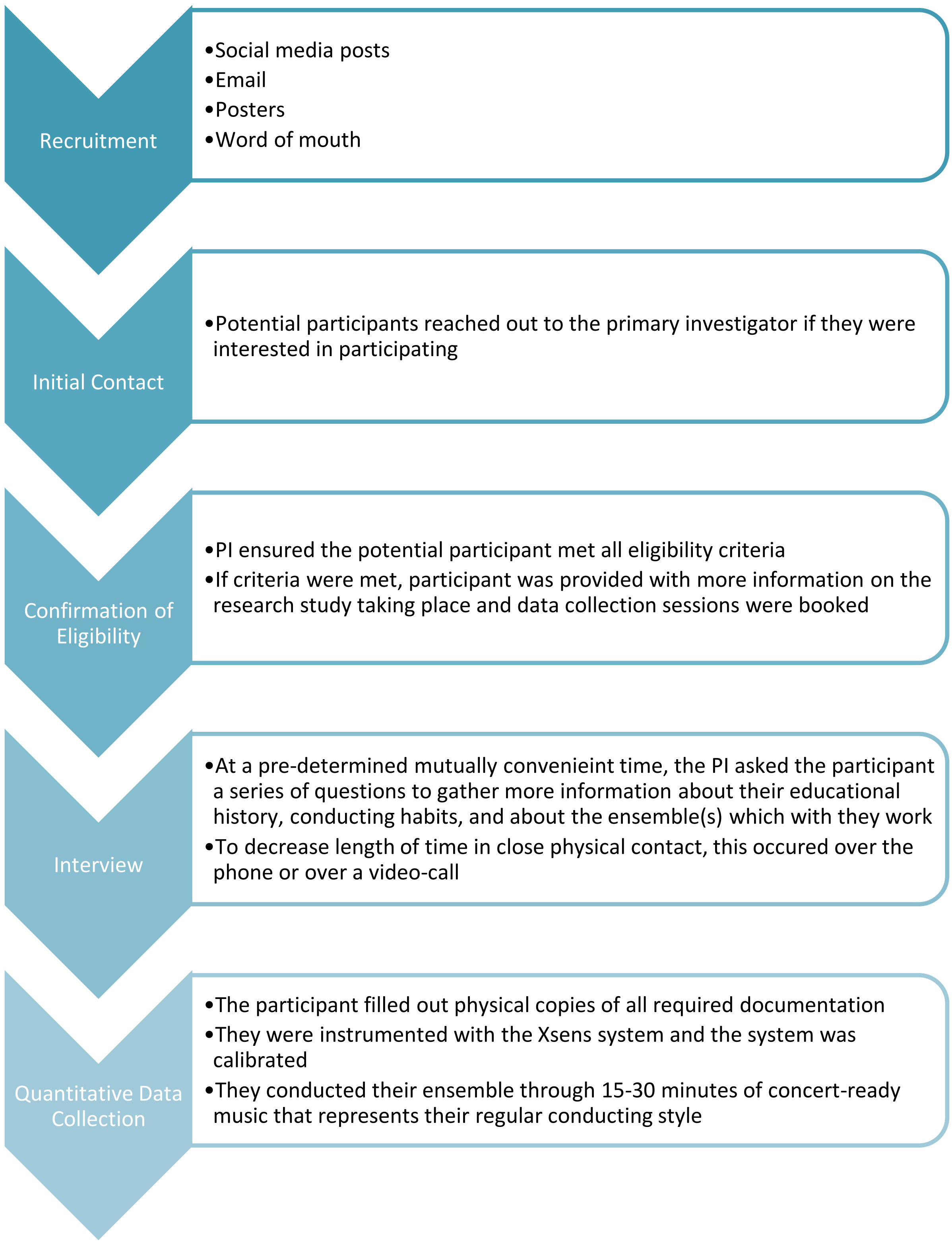
## SIGNATURE OF INVESTIGATOR

These are the terms under which I will conduct research.

_____________________________________ ____________________

Signature of Investigator Date

**Appendix B: Flow chart depicting data collection process**



## Appendix C: Data collection questionnaire

Participant Identification Number:

Date/Time of Interview:

Date/Time/Location of Data Collection:

**About the conductor:**

| | |
|---|---|
| Date of Birth | |
| Biological sex | |
| Preferred pronouns | |
| Handedness | |
| Hand used for main conducting patterns | |
| Educational history specifically related to conducting | |
| Current job | |
| Other significant hobbies (that require physical movement) or sports regularly participated in | |
| Primary musical instrument on which you hold a regular practice schedule | |
| Other musical instrument(s) on which you hold a regular practice schedule | |
| Number of years of conducting experience | |
| Number of hours a week spent conducting (in season) | |
| Past injuries related to conducting | |
| Other injuries in the past that have kept you from conducting or changed how you conducted | |

| | |
|---|---|
| | |
| Baton use – in rehearsal | |
| Baton use – in performance | |
| How much control do you have over your conducting space? What can you change? What can you not change? | |

**About the ensemble with which they work:**

| | |
|---|---|
| School ensemble/community ensemble/other | |
| General age of musicians in the ensemble or age limits | |
| Type of ensemble (i.e., instrumental, orchestra, choral, marching band) | |
| Do the musicians (on average) have individual private training on their instruments? | |
| Approximate size of the ensemble with which you work | |
| Approximate size of the regular ensemble practice space | |
| Do the musicians all read music? | |

**Appendix D: Description of anthropometric measurements as defined by Xsens™**

| Measurement | Description |
|---|---|
| Body Height | Distance from the ground to the top of the head |
| Body Mass | Using a bathroom scale |
| Foot Size | Distance from the back of heel to front of longest toe, or from the heel to toe of shoe if wearing shoes |
| Arm Span | Distance from longest fingertip to fingertip with arms abducted to the horizontal plane |
| Ankle Height | Distance from the floor to the center of the lateral malleolus |
| Hip Height | Distance from the floor to the greater trochanter |
| Hip Width | Distance between right and left anterior superior iliac crests |
| Knee Height | Distance from the floor to the lateral epicondyle of the femur |
| Shoulder Width | Distance between the left and right acromia |
| Shoulder Height | Distance from the floor to the acromia |

*Note: Measurements are to be taken with shoes on.*
*Unilateral measurements are to be taken on the right side of the body*

**Appendix E: Data for individual trials**

**<u>Appendix E.1: Conductor 1</u>**

Table E.1.1: Conductor 1, Neck.

| Rotation | Outcome Variable | Sample # | | | | | | Overall |
|---|---|---|---|---|---|---|---|---|
| | | 02 | 03 | 04 | 05 | 06 | 07 | |
| F/E | Mean | 3.5 | 4.6 | 2.4 | 5.7 | 5.3 | 5.9 | 4.4 |
| | Median | 5.4 | 5.6 | 3.5 | 8.2 | 6.8 | 6.4 | 5.8 |
| | Max | 37.6 | 27.8 | 29.0 | 38.2 | 31.0 | 29.7 | 38.2 |
| | Min | -37.0 | -40.8 | -40.5 | -40.3 | -39.7 | -35.4 | -40.8 |
| | ROM | 74.6 | 68.6 | 69.5 | 78.5 | 70.8 | 65.1 | 78.9 |
| | ISV | 10.5 | 7.8 | 9.9 | 11.9 | 10.5 | 8.3 | 10.0 |
| | Below Neutral | 9.7 | 5.4 | 9.1 | 11.4 | 8.2 | 4.3 | 8.0 |
| | Neutral | 64.6 | 70.7 | 72.8 | 47.4 | 60.1 | 67.2 | 64.3 |
| | Above Neutral | 25.8 | 23.9 | 18.1 | 41.2 | 31.8 | 28.5 | 27.7 |
| RLB/LLB | Mean | -2.4 | -0.8 | -0.9 | -0.7 | -0.3 | -0.6 | -0.9 |
| | Median | -2.2 | -0.5 | -0.6 | -0.5 | 0.2 | -0.6 | -0.7 |
| | Max | 10.2 | 12.5 | 9.3 | 11.2 | 18.4 | 16.5 | 18.4 |
| | Min | -17.4 | -20.6 | -23.4 | -16.4 | -18.0 | -26.9 | -26.9 |
| | ROM | 27.6 | 33.1 | 32.7 | 27.6 | 36.4 | 43.4 | 45.3 |
| | ISV | 4.4 | 4.2 | 4.0 | 4.0 | 4.6 | 5.0 | 4.4 |
| | Below Neutral | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.4 | 0.1 |
| | Neutral | 100.0 | 100.0 | 99.9 | 100.0 | 100.0 | 99.7 | 99.9 |
| | Above Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| RAR/LAR | Mean | 6.8 | 6.9 | 5.8 | 4.9 | 3.7 | 9.0 | 6.1 |
| | Median | 7.4 | 6.9 | 5.8 | 5.3 | 3.5 | 9.2 | 6.2 |
| | Max | 44.7 | 57.2 | 61.1 | 55.2 | 48.0 | 51.4 | 61.1 |
| | Min | -32.7 | -43.6 | -33.5 | -39.4 | -35.5 | -25.1 | -43.6 |
| | ROM | 77.4 | 100.8 | 94.6 | 94.6 | 83.5 | 76.5 | 104.7 |
| | ISV | 9.1 | 9.5 | 10.1 | 10.2 | 9.6 | 8.9 | 9.7 |
| | Below Neutral | 1.1 | 1.0 | 1.4 | 2.3 | 1.4 | 0.2 | 1.3 |
| | Neutral | 94.4 | 93.5 | 95.1 | 93.8 | 95.6 | 93.0 | 94.2 |
| | Above Neutral | 4.6 | 5.6 | 3.6 | 3.9 | 2.9 | 6.9 | 4.5 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

Table E.1.2: Conductor 1, Shoulder.

| Rotation | Outcome Variable | | Sample # 02 | 03 | 04 | 05 | 06 | 07 | Overall |
|---|---|---|---|---|---|---|---|---|---|
| F/E | Right | Mean | 6.3 | 4.5 | 16.5 | 19.2 | 15.6 | 5.9 | 11.4 |
| | | Median | 5.2 | 4.1 | 14.7 | 16.8 | 14.6 | 5.8 | 8.8 |
| | | Max | 55.6 | 48.6 | 98.5 | 112.5 | 76.4 | 66.7 | 97.3 |
| | | Min | -16.0 | -16.2 | -13.0 | -15.2 | -15.6 | -21.8 | -21.8 |
| | | ROM | 71.6 | 64.9 | 111.5 | 127.8 | 92.0 | 88.5 | 119.1 |
| | | ISV | 9.1 | 7.3 | 14.9 | 15.4 | 13.6 | 8.2 | 13.3 |
| | | Below Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 |
| | | Neutral | 92.6 | 97.6 | 62.7 | 59.6 | 64.7 | 94.8 | 78.4 |
| | | Above Neutral | 7.4 | 2.5 | 37.3 | 40.4 | 35.3 | 5.1 | 21.6 |
| | Left | Mean | 6.1 | 4.8 | 17.3 | 19.5 | 17.3 | 6.2 | 12.0 |
| | | Median | 4.1 | 3.4 | 16.2 | 16.8 | 15.9 | 5.1 | 9.2 |
| | | Max | 79.2 | 102.9 | 91.2 | 98.8 | 85.9 | 84.6 | 102.9 |
| | | Min | -26.4 | -25.4 | -25.1 | -24.2 | -24.6 | -28.0 | -28.0 |
| | | ROM | 105.6 | 128.2 | 116.3 | 123.0 | 110.4 | 112.6 | 130.9 |
| | | ISV | 14.9 | 12.8 | 18.4 | 19.8 | 18.0 | 14.0 | 17.6 |
| | | Below Neutral | 1.2 | 0.4 | 0.1 | 0.2 | 0.3 | 0.8 | 0.5 |
| | | Neutral | 86.9 | 91.2 | 58.6 | 57.1 | 59.8 | 87.4 | 73.2 |
| | | Above Neutral | 11.9 | 8.5 | 41.3 | 42.7 | 39.9 | 11.8 | 26.3 |
| ABD/ADD | Right | Mean | 21.7 | 19.3 | 28.1 | 27.8 | 28.0 | 21.4 | 24.4 |
| | | Median | 21.2 | 18.8 | 27.5 | 26.6 | 28.09 | 21.0 | 23.2 |
| | | Max | 45.4 | 41.8 | 55.0 | 63.0 | 551 | 44.3 | 63.0 |
| | | Min | 5.7 | 4.6 | 8.2 | 8.0 | 7.3 | 5.0 | 6.9 |
| | | ROM | 39.7 | 37.2 | 46.8 | 54.9 | 48.3 | 39.2 | 56.0 |
| | | ISV | 5.7 | 4.6 | 8.2 | 8.0 | 7.3 | 5.0 | 7.7 |
| | | Below Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Neutral | 40.5 | 60.1 | 15.8 | 15.7 | 14.1 | 41.9 | 31.7 |
| | | Above Neutral | 59.5 | 39.9 | 84.2 | 84.3 | 85.9 | 58.1 | 68.3 |
| | Left | Mean | 24.1 | 23.9 | 29.3 | 29.9 | 29.1 | 24.7 | 26.9 |
| | | Median | 21.4 | 22.0 | 27.5 | 28.6 | 28.0 | 23.2 | 24.9 |
| | | Max | 64.5 | 61.5 | 65.1 | 66.2 | 63.1 | 67.0 | 67.0 |
| | | Min | 2.7 | 3.6 | 4.7 | 4.9 | 4.2 | 3.4 | 2.7 |
| | | ROM | 61.8 | 57.9 | 60.4 | 615 | 58.9 | 63.7 | 64.3 |
| | | ISV | 10.6 | 8.8 | 11.0 | 11.46 | 11.0 | 9.7 | 10.7 |
| | | Below Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Neutral | 43.1 | 39.0 | 22.9 | 22.1 | 22.46 | 34.6 | 30.6 |
| | | Above Neutral | 56.9 | 61.0 | 77.1 | 77.9 | 77.5 | 65.4 | 69.4 |
| IR/ER | Right | Mean | -23.8 | -22.3 | -15.3 | -10.4 | -18.9 | -21.2 | -18.6 |
| | | Median | -23.8 | -22.5 | -16.7 | -11.9 | -19.9 | -21.4 | -19.8 |
| | | Max | 58.0 | 56.3 | 83.5 | 97.9 | 67.1 | 61.1 | 59.1 |
| | | Min | -48.7 | -45.1 | -42.3 | -38.8 | -47.5 | -46.4 | -48.7 |
| | | ROM | 106.7 | 101.3 | 125.9 | 136.7 | 114.5 | 107.4 | 107.8 |
| | | ISV | 9.6 | 7.9 | 12.7 | 13.4 | 11.8 | 8.6 | 11.8 |
| | | Below Neutral | 64.0 | 62.3 | 39.3 | 22.8 | 49.7 | 56.3 | 49.0 |
| | | Neutral | 36.0 | 37.7 | 59.7 | 75.1 | 50.3 | 43.7 | 50.5 |
| | | Above Neutral | 0.0 | 0.0 | 1.0 | 2.1 | 0.0 | 0.0 | 0.5 |
| | Left | Mean | -12.3 | -10.8 | -9.7 | -5.6 | -7.8 | -12.3 | -9.7 |
| | | Median | -13.5 | -11.9 | -10.3 | -6.8 | -7.9 | -13.3 | -10.9 |
| | | Max | 34.0 | 54.9 | 39.7 | 61.5 | 41.6 | 38.7 | 61.5 |
| | | Min | -38.6 | -34.2 | -40.8 | -37.3 | -39.7 | -43.6 | -43.6 |
| | | ROM | 72.6 | 89.1 | 80.6 | 98.8 | 81.3 | 82.3 | 105.1 |
| | | ISV | 12.7 | 11.2 | 14.6 | 15.3 | 14.4 | 11.5 | 13.6 |
| | | Below Neutral | 28.4 | 18.8 | 26.1 | 18.6 | 0.3 | 23.9 | 22.4 |
| | | Neutral | 69.1 | 79.0 | 70.1 | 75.8 | 59.8 | 74.0 | 74.1 |
| | | Above Neutral | 2.5 | 2.2 | 3.8 | 5.7 | 39.9 | 2.1 | 3.5 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

Table E.1.3: Conductor 1, Elbow.

| Rotation | Outcome Variable | | Sample # 02 | 03 | 04 | 05 | 06 | 07 | Overall |
|---|---|---|---|---|---|---|---|---|---|
| F/E | Right | Mean | 91.7 | 97.1 | 82.1 | 80.1 | 83.6 | 96.5 | 88.4 |
| | | Median | 92.2 | 97.0 | 83.3 | 81.5 | 82.7 | 96.8 | 89.7 |
| | | Max | 145.3 | 131.0 | 142.7 | 130.4 | 145.4 | 131.6 | 145.4 |
| | | Min | -5.3 | 11.9 | 19.2 | 5.06 | 20.4 | -2.5 | -5.3 |
| | | ROM | 140.6 | 119.1 | 123.5 | 1251 | 125.0 | 134.1 | 150.7 |
| | | ISV | 17.3 | 11.9 | 19.9 | 18.8 | 20.4 | 14.6 | 18.7 |
| | | Below Neutral | 3.0 | 0.5 | 13.5 | 14.3 | 13.0 | 1.0 | 7.7 |
| | | Neutral | 71.5 | 61.3 | 70.7 | 72.3 | 68.6 | 61.6 | 67.6 |
| | | Above Neutral | 25.5 | 38.1 | 15.8 | 13.4 | 18.4 | 37.4 | 24.7 |
| | Left | Mean | 103.1 | 110.0 | 90.9 | 90.0 | 90.3 | 111.2 | 99.0 |
| | | Median | 107.8 | 114.7 | 94.2 | 94.1 | 94.4 | 115.8 | 104.6 |
| | | Max | 134.7 | 158.1 | 147.6 | 148.3 | 137.2 | 146.2 | 158.1 |
| | | Min | 1.2 | 20.5 | -0.3 | 1.6 | 10.5 | 6.4 | -0.32 |
| | | ROM | 133.5 | 137.6 | 147.9 | 146.7 | 126.8 | 139.8 | 158. |
| | | ISV | 19.1 | 16.5 | 22.6 | 24.1 | 23.1 | 18.9 | 22.79 |
| | | Below Neutral | 2.8 | 1.7 | 9.9 | 11.6 | 10.2 | 2.3 | 68 |
| | | Neutral | 26.0 | 15.7 | 51.6 | 50.8 | 51.4 | 14.2 | 35.4 |
| | | Above Neutral | 71.2 | 82.6 | 38.5 | 37.7 | 38.4 | 83.5 | 58.2 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

Table E.1.4: Conductor 1, Wrist.

| Rotation | Outcome Variable | | Sample # 02 | 03 | 04 | 05 | 06 | 07 | Overall |
|---|---|---|---|---|---|---|---|---|---|
| F/E | Right | Mean | -39.5 | -39.2 | -34.8 | -39.2 | -33.9 | -40.0 | -37.7 |
| | | Median | -42.0 | -41.0 | -38.7 | -42.7 | -38.5 | -42.7 | -40.8 |
| | | Max | 40.7 | 35.6 | 60.7 | 51.7 | 58.2 | 47.2 | 6.7 |
| | | Min | -50.7 | -49.9 | -54.0 | -54.8 | -54.7 | -54.3 | -54.8 |
| | | ROM | 91.3 | 85.5 | 114.7 | 106.5 | 112.9 | 101.5 | 61.4 |
| | | ISV | 6.7 | 5.7 | 9.9 | 9.4 | 12.0 | 7.8 | 9.1 |
| | | Below Neutral | 100.0 | 100.0 | 99.8 | 99.8 | 99.2 | 100.0 | 99.8 |
| | | Neutral | 0.0 | 0.0 | 0.2 | 0.2 | 0.8 | 0.0 | 0.2 |
| | | Above Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Left | Mean | -11.8 | -11.1 | -8.4 | -13.3 | -11.7 | -14.7 | -11.6 |
| | | Median | -17.2 | -15.5 | -15.2 | -20.0 | -20.1 | -23.0 | -17.6 |
| | | Max | 42.5 | 45.9 | 45.3 | 51.1 | 49.2 | 62.3 | 62.3 |
| | | Min | -36.1 | -39.6 | -40.2 | -46.9 | -47.4 | -43.9 | -47.4 |
| | | ROM | 78.6 | 85.6 | 85.5 | 98.1 | 96.6 | 106.1 | 109.7 |
| | | ISV | 16.3 | 15.0 | 20.2 | 20.3 | 23.4 | 20.3 | 19.4 |
| | | Below Neutral | 75.5 | 74.8 | 64.8 | 73.8 | 68.6 | 74.4 | 71.8 |
| | | Neutral | 7.7 | 9.8 | 11.5 | 6.7 | 8.5 | 6.5 | 8.7 |
| | | Above Neutral | 16.8 | 15.5 | 23.7 | 19.6 | 22.9 | 19.2 | 19.6 |
| RD/UD | Right | Mean | 3.6 | 3.5 | 2.2 | 4.7 | 3.3 | 5.6 | 3.7 |
| | | Median | 3.8 | 3.8 | 3.14 | 5.6 | 4.9 | 6.1 | 4.3 |
| | | Max | 25.4 | 30.0 | 29. | 37.6 | 31.09 | 27.3 | 15.2 |
| | | Min | -14.3 | -19.4 | -16.5 | -22.5 | -161 | -14.2 | -22.5 |
| | | ROM | 39.8 | 49.4 | 45.8 | 60.1 | 47.7 | 41.6 | 37.6 |
| | | ISV | 3.0 | 2.7 | 4.7 | 5.0 | 5.9 | 3.5 | 4.4 |
| | | Below Neutral | 0.5 | 0.4 | 9.3 | 3.4 | 11.64 | 1.2 | 4.5 |
| | | Neutral | 63.2 | 68.1 | 57.4 | 42.3 | 38. | 35.4 | 52.2 |
| | | Above Neutral | 36.3 | 31.5 | 33.2 | 54.3 | 49.63 | 63.4 | 43.3 |
| | Left | Mean | -1.4 | -1.3 | -6.4 | -5.2 | -5. | -3.3 | -3.9 |
| | | Median | 1.8 | 0.5 | -3.1 | -1.8 | -2.4 | -1.3 | -0.9 |
| | | Max | 13.2 | 17.0 | 12.4 | 17.5 | 17.14 | 15.1 | 17.5 |
| | | Min | -38.6 | -40.6 | -45.5 | -45.0 | -43. | -47.0 | -47.0 |
| | | ROM | 51.8 | 57.5 | 57.9 | 62.5 | 60.35 | 62.1 | 64.5 |
| | | ISV | 10.1 | 9.3 | 11.8 | 12.2 | 134 | 11.4 | 11.5 |
| | | Below Neutral | 28.2 | 29.1 | 45.1 | 39.6 | 43.8 | 36.6 | 37.1 |
| | | Neutral | 39.6 | 40.5 | 41.1 | 42.3 | 30.2 | 34.8 | 38.4 |
| | | Above Neutral | 32.2 | 30.4 | 13.8 | 18.1 | 25.9 | 28.6 | 24.6 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| P/S | Right | Mean | 101.9 | 76.4 | 81.3 | 100.2 | 99.5 | 103.3 | 92.2 |
| | | Median | 117.9 | 103.2 | 111.9 | 113.7 | 116.9 | 116.1 | 114.1 |
| | | Max | 158.7 | 160.0 | 160.5 | 150.8 | 138.6 | 150.9 | 158.7 |
| | | Min | 2.2 | -9.5 | -9.6 | 17.2 | 1.8 | 24.5 | -9.6 |
| | | ROM | 156.5 | 169.4 | 170.0 | 133.6 | 136.8 | 126.4 | 168.2 |
| | | ISV | 34.8 | 53.1 | 51.0 | 30.4 | 35.7 | 28.7 | 43.0 |
| | | Below Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Neutral | 3.0 | 25.88 | 20.3 | 0.1 | 2.8 | 0.0 | 10.2 |
| | | Above Neutral | 97.0 | 749 | 79.7 | 99.9 | 97.2 | 100.0 | 89.9 |
| | Left | Mean | 81.6 | 57.1 | 68.1 | 85.1 | 85.5 | 79.0 | 74.8 |
| | | Median | 99.3 | 82.7 | 94.5 | 101.8 | 101.8 | 96.0 | 96.2 |
| | | Max | 141.6 | 151.1 | 148.2 | 151.3 | 139.2 | 144.6 | 151.3 |
| | | Min | -10.9 | -16.4 | -7.6 | -8.9 | -13.2 | -10.6 | -16.4 |
| | | ROM | 152.5 | 167.5 | 155.8 | 160.2 | 152.4 | 155.2 | 167.7 |
| | | ISV | 39.1 | 47.5 | 48.2 | 39.8 | 40.4 | 37.9 | 44.3 |
| | | Below Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Neutral | 14.5 | 37.2 | 31.6 | 14.3 | 14.6 | 15.9 | 22.7 |
| | | Above Neutral | 85.5 | 62.8 | 68.4 | 85.7 | 85.5 | 84.1 | 77.4 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

Table E.1.5: Conductor 1, Trunk.

| Rotation | Outcome Variable | Sample # 02 | 03 | 04 | 05 | 06 | 07 | Overall |
|---|---|---|---|---|---|---|---|---|
| F/E | Mean | -0.2 | 2.7 | -0.7 | -2.1 | -1.1 | 3.9 | 0.4 |
| | Median | -0.6 | 2.8 | -0.8 | -2.3 | -2.2 | 3.4 | 0.1 |
| | Max | 24.2 | 26.3 | 27.4 | 22.6 | 28.2 | 25.8 | 28.2 |
| | Min | -12.2 | 22.8 | -20.4 | -13.0 | -13.2 | -12.0 | -20.4 |
| | ROM | 36.4 | -14.2 | 47.8 | 35.6 | 41.4 | 37.8 | 48.6 |
| | ISV | 4.7 | 37.0 | 4.9 | 4.7 | 6.3 | 5.0 | 5.4 |
| | Below Neutral | 15.6 | 4.4 | 18.8 | 24.8 | 24.7 | 1.8 | 15.1 |
| | Neutral | 70.8 | 68.0 | 71.7 | 69.0 | 62.1 | 61.6 | 67.5 |
| | Above Neutral | 13.7 | 27.5 | 9.5 | 6.2 | 13.3 | 36.6 | 17.4 |
| RLB/LLB | Mean | 1.2 | 0.8 | 1.2 | 1.3 | 0.8 | 1.0 | 1.0 |
| | Median | 1.6 | 0.9 | 1.3 | 1.3 | 1.2 | 1.3 | 1.3 |
| | Max | 12.5 | 14.7 | 9.9 | 16.8 | 14.8 | 19.4 | 19.4 |
| | Min | -12.7 | -15.3 | -14.5 | -10.3 | -11.6 | -17.0 | -17.0 |
| | ROM | 25.2 | 30.0 | 24.4 | 27.1 | 26.4 | 36.4 | 36.4 |
| | ISV | 4.1 | 4.8 | 3.1 | 3.6 | 4.0 | 6.6 | 4.4 |
| | Below Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Neutral | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| | Above Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| RAR/LAR | Mean | 1.6 | 1.7 | 1.9 | 1.5 | 1.8 | 1.8 | 1.7 |
| | Median | 1.6 | 1.7 | 1.8 | 1.4 | 1.8 | 1.9 | 1.7 |
| | Max | 11.4 | 11.1 | 11.4 | 10.9 | 8.1 | 11.3 | 11.4 |
| | Min | -9.7 | -9.6 | -6.0 | -6.5 | -7.3 | -13.1 | -13.1 |
| | ROM | 21.0 | 20.7 | 17.3 | 17.4 | 15.5 | 24.3 | 24.4 |
| | ISV | 3.4 | 3.8 | 3.1 | 3.0 | 2.6 | 3.7 | 3.3 |
| | Below Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Neutral | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| | Above Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

**Appendix E.2: Conductor 2**

Table E.2.1: Conductor 2, Neck.

| Rotation | Outcome Variable | Sample # | | | | | | | | Overall |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 5 | 9 | 15 | 17 | 18 | 19 | 21 | 23 | |
| F/E | Mean | 16.2 | 15.1 | 14.8 | 16.6 | 17.5 | 25.0 | 18.2 | 20.2 | 17.5 |
| | Median | 19.1 | 18.2 | 17.3 | 19.9 | 21.8 | 26.4 | 20.7 | 22.2 | 21.2 |
| | Max | 27.3 | 31.8 | 39.2 | 37.8 | 41.4 | 41.9 | 36.3 | 42.3 | 42.3 |
| | Min | -6.4 | -12.1 | -12.6 | -7.4 | -10.3 | -2.8 | -10.6 | -3.8 | -12.5 |
| | ROM | 33.7 | 43.9 | 51.7 | 45.1 | 51.7 | 44.7 | 46.9 | 46.1 | 54.9 |
| | ISV | 7.9 | 10.8 | 13.8 | 9.5 | 11.4 | 8.3 | 9.4 | 8.7 | 11.2 |
| | Below Neutral | 0.0 | 0.4 | 0.3 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.1 |
| | Neutral | 21.1 | 31.7 | 40.9 | 26.7 | 30.2 | 8.4 | 19.4 | 14.4 | 27.6 |
| | Above Neutral | 78.9 | 67.9 | 58.9 | 74.3 | 69.8 | 91.6 | 80.5 | 85.6 | 72.3 |
| RLB/LLB | Mean | -0.8 | 0.2 | -2.2 | 0.0 | 0.5 | 1.0 | 0.5 | 0.1 | -0.1 |
| | Median | -0.7 | 0.2 | -2.1 | 0.1 | 0.4 | 0.9 | 0.2 | -0.3 | -0.1 |
| | Max | 7.6 | 13.8 | 6.6 | 16.1 | 15.0 | 11.5 | 19.4 | 25.0 | 25.0 |
| | Min | -7.5 | -12.4 | -16.7 | -15.2 | -12.8 | -10.6 | -9.2 | -10.0 | -16.7 |
| | ROM | 15.0 | 26.2 | 23.2 | 31.4 | 27.8 | 22.1 | 28.6 | 35.0 | 41.7 |
| | ISV | 2.4 | 3.5 | 3.8 | 3.9 | 3.8 | 3.1 | 4.0 | 4.1 | 3.8 |
| | Below Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Neutral | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 99.5 | 100.0 |
| | Above Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | 0.0 |
| RAR/LAR | Mean | 8.7 | 8.8 | 8.9 | 9.2 | 10.4 | 2.7 | 3.7 | 2.9 | 8.4 |
| | Median | 9.6 | 9.3 | 8.6 | 8.8 | 9.6 | 2.3 | 3.3 | 3.9 | 7.9 |
| | Max | 35.7 | 31.0 | 45.7 | 48.0 | 46.1 | 28.6 | 38.8 | 24.0 | 48.0 |
| | Min | -42.6 | -41.0 | -31.1 | -51.1 | -45.7 | -45.4 | -43.4 | -32.5 | -51.1 |
| | ROM | 78.4 | 72.0 | 76.7 | 99.2 | 91.9 | 74.0 | 82.2 | 56.5 | 99.2 |
| | ISV | 11.7 | 11.3 | 13.3 | 14.6 | 14.1 | 8.6 | 12.0 | 8.9 | 13.3 |
| | Below Neutral | 4.5 | 1.5 | 3.8 | 5.3 | 3.5 | 2.0 | 3.4 | 2.9 | 3.6 |
| | Neutral | 85.9 | 84.2 | 81.2 | 79.0 | 75.0 | 95.0 | 90.3 | 95.6 | 81.2 |
| | Above Neutral | 9.7 | 14.3 | 15.0 | 15.7 | 21.6 | 3.0 | 6.4 | 1.5 | 15.2 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

Table E.2.2: Conductor 2, Shoulder.

| Rotation | Outcome Variable | | Sample # 5 | 9 | 15 | 17 | 18 | 19 | 21 | 23 | Overall |
|---|---|---|---|---|---|---|---|---|---|---|---|
| F/E | Right | Mean | 43.7 | 47.1 | 59.6 | 50.5 | 54.0 | 39.7 | 48.3 | 32.3 | 50.6 |
| | | Median | 43.5 | 47.7 | 59.4 | 50.5 | 52.3 | 39.4 | 48.6 | 34.9 | 50.2 |
| | | Max | 91.3 | 96.8 | 97.7 | 96.2 | 115.6 | 89.6 | 91.3 | 94.4 | 105.8 |
| | | Min | -12.0 | -2.3 | -6.9 | -4.7 | -9.8 | 5.9 | -4.2 | -8.5 | -12.0 |
| | | ROM | 103.3 | 99.1 | 104.6 | 100.8 | 125.4 | 83.6 | 95.5 | 102.8 | 117.7 |
| | | ISV | 9.9 | 14.4 | 11.5 | 12.2 | 15.7 | 12.3 | 12.5 | 19.8 | 15.7 |
| | | Below Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Neutral | 1.9 | 4.4 | 0.5 | 1.1 | 0.7 | 3.9 | 1.6 | 22.0 | 2.5 |
| | | Above Neutral | 98.1 | 95.6 | 99.5 | 98.9 | 99.3 | 96.1 | 98.4 | 78.0 | 97.5 |
| | Left | Mean | 26.7 | 30.2 | 41.2 | 28.3 | 33.9 | 27.0 | 28.2 | 30.4 | 32.4 |
| | | Median | 13.3 | 30.5 | 42.4 | 29.6 | 34.2 | 26.8 | 30.6 | 29.7 | 32.7 |
| | | Max | 87.3 | 81.8 | 85.6 | 83.2 | 109.9 | 70.3 | 78.2 | 82.4 | 109.9 |
| | | Min | -0.1 | 1.3 | -4.0 | -7.8 | -11.4 | -0.2 | -2.7 | 0.7 | -11.4 |
| | | ROM | 87.4 | 80.6 | 89.6 | 90.9 | 121.3 | 70.5 | 80.9 | 81.6 | 121.3 |
| | | ISV | 24.7 | 20.6 | 19.6 | 19.0 | 21.9 | 16.6 | 18.4 | 18.3 | 20.9 |
| | | Below Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Neutral | 51.5 | 35.3 | 16.0 | 32.7 | 29.3 | 33.7 | 35.5 | 27.8 | 30.0 |
| | | Above Neutral | 48.5 | 64.7 | 84.0 | 67.4 | 70.7 | 66.3 | 64.5 | 72.2 | 70.0 |
| ABD/ ADD | Right | Mean | 26.3 | 26.5 | 29.7 | 24.2 | 26.8 | 24.8 | 29.2 | 29.7 | 26.9 |
| | | Median | 26.8 | 27.1 | 29.7 | 24.3 | 27.2 | 25.6 | 30.0 | 30.5 | 27.2 |
| | | Max | 47.0 | 56.0 | 53.8 | 71.0 | 85.2 | 43.9 | 60.9 | 62.6 | 69.3 |
| | | Min | 4.8 | -0.4 | 1.1 | -11.0 | -16.0 | 1.5 | -6.8 | -1.7 | -16.0 |
| | | ROM | 42.3 | 56.4 | 52.7 | 82.0 | 101.2 | 42.4 | 67.6 | 64.3 | 85.2 |
| | | ISV | 4.8 | 7.8 | 7.1 | 7.9 | 8.9 | 6.2 | 7.7 | 9.0 | 8.2 |
| | | Below Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Neutral | 7.1 | 16.3 | 6.6 | 24.7 | 18.5 | 16.7 | 10.4 | 12.0 | 16.2 |
| | | Above Neutral | 92.9 | 83.7 | 93.4 | 75.3 | 81.5 | 83.3 | 89.6 | 88.0 | 83.9 |
| | Left | Mean | 23.7 | 27.2 | 39.4 | 28.8 | 31.2 | 27.5 | 30.8 | 29.8 | 31.0 |
| | | Median | 18.2 | 29.3 | 41.6 | 32.0 | 33.3 | 32.3 | 33.8 | 32.2 | 33.5 |
| | | Max | 60.0 | 62.4 | 68.2 | 70.6 | 72.4 | 61.0 | 59.1 | 63.6 | 72.4 |
| | | Min | 4.9 | 6.0 | 8.6 | 3.3 | 4.8 | 6.7 | 3.1 | 4.2 | 3.1 |
| | | ROM | 55.1 | 56.4 | 59.6 | 67.3 | 67.7 | 54.4 | 56.0 | 59.5 | 69.3 |
| | | ISV | 12.3 | 11.4 | 12.8 | 12.1 | 12.6 | 11.5 | 12.8 | 11.4 | 12.9 |
| | | Below Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Neutral | 53.7 | 36.0 | 13.3 | 30.5 | 25.8 | 34.8 | 28.8 | 21.8 | 27.4 |
| | | Above Neutral | 46.4 | 64.0 | 86.8 | 69.5 | 74.2 | 65.2 | 71.2 | 78.2 | 72.6 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| IR/ER | Right | Mean | -0.6 | 0.4 | 16.9 | 4.9 | 10.1 | 0.2 | 3.1 | -8.8 | 6.8 |
| | | Median | -1.9 | 0.1 | 17.2 | 4.1 | 9.5 | 0.1 | 3.2 | -9.0 | 5.6 |
| | | Max | 57.9 | 68.1 | 70.3 | 57.1 | 84.6 | 56.2 | 61.5 | 72.4 | 56.7 |
| | | Min | -11.1 | -28.0 | -27.2 | -19.2 | -27.9 | -29.8 | -22.5 | -33.2 | -33.2 |
| | | ROM | 69.0 | 96.0 | 97.5 | 76.3 | 112.5 | 86.0 | 84.0 | 105.5 | 89.9 |
| | | ISV | 6.9 | 10.2 | 9.3 | 8.6 | 12.8 | 8.2 | 8.8 | 10.3 | 12.4 |
| | | Below Neutral | 0.0 | 2.7 | 0.2 | 0.0 | 0.5 | 0.2 | 0.2 | 15.4 | 1.3 |
| | | Neutral | 97.9 | 93.5 | 62.4 | 94.8 | 78.1 | 98.6 | 97.8 | 83.5 | 83.6 |
| | | Above Neutral | 2.1 | 3.9 | 37.4 | 5.2 | 21.4 | 1.3 | 2.0 | 1.1 | 15.1 |
| | Left | Mean | -7.7 | -7.8 | -6.0 | -9.5 | -5.9 | -12.8 | -11.0 | -10.3 | -7.8 |
| | | Median | -12.7 | -11.0 | -5.4 | -10.8 | -6.7 | -14.8 | -13.2 | -12.9 | -9.1 |
| | | Max | 58.6 | 40.9 | 30.0 | 28.6 | 49.3 | 18.3 | 27.7 | 27.1 | 58.6 |
| | | Min | -27.1 | -36.5 | -43.2 | -42.2 | -45.9 | -43.7 | -35.0 | -43.6 | -45.9 |
| | | ROM | 85.7 | 77.4 | 73.2 | 70.8 | 95.2 | 62.0 | 62.8 | 70.7 | 104.5 |
| | | ISV | 12.9 | 13.3 | 14.4 | 12.9 | 14.2 | 12.1 | 11.2 | 13.0 | 13.7 |
| | | Below Neutral | 9.6 | 16.9 | 19.3 | 23.2 | 17.8 | 32.5 | 21.7 | 25.2 | 20.2 |
| | | Neutral | 87.7 | 79.0 | 78.4 | 74.6 | 77.6 | 67.5 | 78.0 | 74.3 | 76.9 |
| | | Above Neutral | 2.7 | 4.1 | 2.4 | 2.2 | 4.6 | 0.0 | 0.3 | 0.8 | 3.0 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

Table E.2.3: Conductor 2, Elbow.

| Rotation | Outcome Variable | | Sample # 5 | 9 | 15 | 17 | 18 | 19 | 21 | 23 | Overall |
|---|---|---|---|---|---|---|---|---|---|---|---|
| F/E | Right | Mean | 80.1 | 65.2 | 51.8 | 59.2 | 57.1 | 63.6 | 61.5 | 73.8 | 59.9 |
| | | Median | 82.4 | 65.9 | 51.3 | 59.7 | 58.2 | 64.5 | 61.0 | 77.2 | 60.5 |
| | | Max | 101.0 | 106.5 | 113.5 | 109.0 | 141.7 | 127.0 | 128.8 | 156.5 | 156.5 |
| | | Min | 12.0 | 2.4 | 1.7 | -2.3 | -6.7 | 15.3 | 13.0 | 1.4 | -6.6 |
| | | ROM | 89.0 | 104.1 | 111.8 | 111.4 | 148.4 | 111.7 | 115.9 | 155.2 | 163.2 |
| | | ISV | 12.1 | 15.9 | 16.3 | 16.0 | 24.5 | 19.3 | 17.9 | 29.7 | 21.7 |
| | | Below Neutral | 4.0 | 37.0 | 69.2 | 50.6 | 52.6 | 42.7 | 47.5 | 28.4 | 49.0 |
| | | Neutral | 95.9 | 62.7 | 30.7 | 49.2 | 44.0 | 55.0 | 50.5 | 59.1 | 49.6 |
| | | Above Neutral | 0.1 | 0.9 | 0.2 | 0.2 | 3.5 | 2.4 | 2.0 | 12.5 | 2.4 |
| | Left | Mean | 25.2 | 38.5 | 52.1 | 41.2 | 38.3 | 45.1 | 43.5 | 57.7 | 42.1 |
| | | Median | 10.5 | 28.9 | 50.4 | 39.4 | 33.9 | 46.4 | 41.9 | 62.2 | 40.0 |
| | | Max | 96.6 | 150.4 | 165.7 | 122.1 | 159.4 | 152.1 | 152.5 | 131.4 | 165.7 |
| | | Min | -0.6 | -20.6 | -11.8 | -5.0 | -21.4 | -8.2 | -2.0 | -2.9 | -21.4 |
| | | ROM | 97.2 | 171.0 | 177.4 | 127.2 | 180.8 | 160.3 | 154.5 | 134.2 | 187.0 |
| | | ISV | 26.6 | 34.8 | 34.6 | 28.3 | 32.0 | 34.9 | 33.8 | 33.3 | 33.0 |
| | | Below Neutral | 83.8 | 70.2 | 63.9 | 70.3 | 74.5 | 63.2 | 68.3 | 45.1 | 69.5 |
| | | Neutral | 16.2 | 24.7 | 27.5 | 28.3 | 21.5 | 31.8 | 25.3 | 43.6 | 25.7 |
| | | Above Neutral | 0.0 | 5.0 | 8.6 | 1.4 | 4.0 | 5.0 | 6.4 | 11.4 | 4.8 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

Table E.2.4: Conductor 2, Wrist.

| Rotation | Outcome Variable | | Sample # 5 | 9 | 15 | 17 | 18 | 19 | 21 | 23 | Overall |
|---|---|---|---|---|---|---|---|---|---|---|---|
| F/E | Right | Mean | -21.4 | -20.6 | -14.1 | -18.8 | -16.6 | 39.7 | -12.3 | -18.8 | -12.8 |
| | | Median | -22.6 | -21.9 | -14.9 | -19.6 | -19.0 | 39.4 | -13.4 | -19.4 | -17.6 |
| | | Max | 28.6 | 37.2 | 30.6 | 37.1 | 44.8 | 89.6 | 39.0 | 27.4 | 89.6 |
| | | Min | -27.0 | -31.4 | -23.8 | -31.1 | -29.8 | 5.9 | -22.4 | -27.1 | -31.4 |
| | | ROM | 55.5 | 68.6 | 54.4 | 68.2 | 74.5 | 83.6 | 61.4 | 54.5 | 120.9 |
| | | ISV | 3.8 | 5.6 | 4.2 | 5.1 | 7.8 | 12.3 | 5.6 | 4.5 | 16.4 |
| | | Below Neutral | 99.5 | 97.9 | 96.9 | 98.4 | 89.9 | 0.0 | 90.8 | 98.3 | 87.3 |
| | | Neutral | 0.5 | 2.0 | 3.0 | 1.6 | 8.2 | 0.0 | 7.5 | 1.7 | 4.5 |
| | | Above Neutral | 0.0 | 0.1 | 0.1 | 0.1 | 1.9 | 100.0 | 1.7 | 0.0 | 8.2 |
| | Left | Mean | -4.1 | -5.6 | -7.1 | -8.0 | -6.9 | 27.0 | -8.3 | -10.2 | -4.7 |
| | | Median | -2.4 | -5.9 | -7.5 | -8.8 | -7.2 | 26.8 | -9.3 | -11.1 | -6.8 |
| | | Max | 12.7 | 19.1 | 13.5 | 24.5 | 20.9 | 70.3 | 23.4 | 6.4 | 70.3 |
| | | Min | -19.7 | -19.0 | -27.4 | -20.7 | -21.6 | -0.2 | -20.1 | -19.3 | -27.4 |
| | | ROM | 32.4 | 38.1 | 40.9 | 45.2 | 42.5 | 70.5 | 43.5 | 25.7 | 97.7 |
| | | ISV | 5.4 | 7.1 | 7.5 | 5.4 | 7.1 | 16.6 | 5.6 | 4.5 | 11.9 |
| | | Below Neutral | 35.1 | 52.3 | 59.9 | 69.8 | 57.9 | 0.0 | 71.1 | 80.8 | 56.5 |
| | | Neutral | 61.8 | 39.4 | 36.2 | 28.9 | 36.7 | 7.6 | 27.3 | 19.1 | 33.0 |
| | | Above Neutral | 3.2 | 8.4 | 4.0 | 1.3 | 5.3 | 92.4 | 1.6 | 0.1 | 10.5 |
| RD/UD | Right | Mean | 11.8 | 9.1 | 12.7 | 11.1 | 8.4 | 24.8 | 5.1 | 14.8 | 11.0 |
| | | Median | 13.3 | 10.6 | 14.4 | 12.4 | 9.8 | 25.6 | 6.5 | 15.2 | 11.7 |
| | | Max | 41.2 | 61.4 | 66.5 | 59.3 | 64.1 | 43.9 | 66.6 | 47.8 | 43.9 |
| | | Min | -11.5 | -27.6 | -33.9 | -28.6 | -34.6 | 1.5 | -39.0 | -14.7 | -39.0 |
| | | ROM | 52.8 | 89.0 | 100.4 | 87.9 | 98.7 | 42.4 | 105.7 | 62.5 | 82.9 |
| | | ISV | 6.4 | 7.9 | 8.2 | 6.8 | 7.6 | 6.2 | 8.2 | 7.3 | 8.7 |
| | | Below Neutral | 2.4 | 5.3 | 4.2 | 2.0 | 5.6 | 0.0 | 10.9 | 0.7 | 4.3 |
| | | Neutral | 13.1 | 19.2 | 10.9 | 16.1 | 20.8 | 1.3 | 30.2 | 9.6 | 16.6 |
| | | Above Neutral | 84.5 | 75.5 | 84.9 | 81.9 | 73.7 | 98.8 | 58.9 | 89.7 | 79.1 |
| | Left | Mean | 5.6 | 7.8 | 5.3 | 8.4 | 7.0 | 27.5 | 10.0 | 17.9 | 9.3 |
| | | Median | 4.2 | 7.6 | 6.9 | 9.9 | 7.3 | 32.3 | 10.8 | 19.7 | 9.5 |
| | | Max | 36.5 | 45.0 | 30.7 | 37.8 | 44.7 | 61.0 | 35.8 | 38.4 | 61.0 |
| | | Min | -49.6 | -39.4 | -43.8 | -43.4 | -41.6 | 6.7 | -42.5 | -17.2 | -49.6 |
| | | ROM | 86.1 | 84.4 | 74.5 | 81.2 | 86.3 | 54.4 | 78.3 | 55.7 | 110.6 |
| | | ISV | 8.5 | 12.4 | 11.8 | 11.9 | 12.0 | 11.5 | 12.2 | 11.7 | 13.2 |
| | | Below Neutral | 4.1 | 11.0 | 16.7 | 11.7 | 14.4 | 0.0 | 11.1 | 2.1 | 11.7 |
| | | Neutral | 48.7 | 34.4 | 28.2 | 25.1 | 28.8 | 0.0 | 20.8 | 16.5 | 26.1 |
| | | Above Neutral | 47.2 | 54.6 | 55.1 | 63.2 | 56.8 | 100.0 | 68.2 | 81.4 | 62.2 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| P/S | Right | Mean | 69.1 | 55.3 | 51.6 | 55.7 | 37.6 | 19.0 | 34.8 | 46.6 | 44.3 |
| | | Median | 68.1 | 56.8 | 51.1 | 56.6 | 40.4 | 18.7 | 36.6 | 45.5 | 47.3 |
| | | Max | 105.3 | 115.4 | 116.2 | 96.0 | 158.4 | 114.4 | 134.2 | 156.1 | 115.1 |
| | | Min | 7.0 | -9.5 | -5.3 | 4.0 | -51.1 | -38.3 | -29.8 | -41.1 | -51.1 |
| | | ROM | 98.3 | 124.9 | 121.5 | 92.0 | 209.4 | 152.7 | 163.9 | 197.2 | 166.1 |
| | | ISV | 7.1 | 16.9 | 15.8 | 13.0 | 23.1 | 16.9 | 20.9 | 31.5 | 23.0 |
| | | Below Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 1.7 | 2.2 | 0.7 | 5.9 | 1.2 |
| | | Neutral | 0.0 | 2.8 | 1.9 | 0.8 | 19.5 | 50.8 | 22.6 | 5.8 | 13.5 |
| | | Above Neutral | 100.0 | 97.2 | 98.1 | 99.2 | 78.8 | 47.0 | 76.7 | 88.3 | 85.4 |
| | Left | Mean | 78.0 | 62.3 | 58.8 | 72.6 | 71.8 | 62.9 | 73.0 | 64.7 | 68.6 |
| | | Median | 98.3 | 70.3 | 64.3 | 71.6 | 78.9 | 61.2 | 78.3 | 60.8 | 74.0 |
| | | Max | 135.6 | 140.0 | 146.7 | 137.4 | 143.9 | 133.2 | 140.2 | 119.4 | 146.6 |
| | | Min | -7.4 | -72.6 | -63.8 | -31.1 | -56.6 | -20.0 | -36.8 | -21.1 | -72.6 |
| | | ROM | 143.0 | 212.6 | 210.4 | 168.5 | 200.6 | 153.1 | 176.9 | 140.6 | 219.3 |
| | | ISV | 36.8 | 42.1 | 43.0 | 31.2 | 37.6 | 39.9 | 38.7 | 33.2 | 38.3 |
| | | Below Neutral | 0.0 | 2.7 | 3.4 | 0.1 | 0.7 | 0.0 | 0.3 | 0.1 | 1.0 |
| | | Neutral | 14.0 | 15.9 | 17.2 | 4.2 | 10.8 | 17.1 | 11.2 | 9.6 | 11.6 |
| | | Above Neutral | 86.0 | 81.3 | 79.4 | 95.7 | 88.4 | 82.9 | 88.5 | 90.3 | 87.3 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

Table E.2.5: Conductor 2, Trunk.

| Rotation | Outcome Variable | Sample # 5 | 9 | 15 | 17 | 18 | 19 | 21 | 23 | Overall |
|---|---|---|---|---|---|---|---|---|---|---|
| F/E | Mean | -4.1 | -1.3 | -5.6 | -7.0 | -7.2 | -10.2 | -8.7 | -11.1 | -6.8 |
| | Median | -4.4 | -1.4 | -5.7 | -7.2 | -7.2 | -10.7 | -9.0 | -11.2 | -7.2 |
| | Max | 10.4 | 17.2 | 18.8 | 18.6 | 21.0 | 11.8 | 14.0 | 5.3 | 20.9 |
| | Min | -12.3 | -18.4 | -19.4 | -25.1 | -26.6 | -23.6 | -30.6 | -26.9 | -30.6 |
| | ROM | 22.7 | 35.7 | 38.1 | 43.7 | 47.5 | 35.4 | 45.4 | 32.2 | 51.5 |
| | ISV | 3.9 | 5.9 | 6.3 | 5.1 | 5.8 | 4.4 | 6.0 | 4.0 | 6.0 |
| | Below Neutral | 38.5 | 23.4 | 55.1 | 68.1 | 71.0 | 89.3 | 81.5 | 92.7 | 66.1 |
| | Neutral | 58.4 | 63.1 | 39.5 | 30.3 | 25.4 | 9.0 | 14.9 | 7.1 | 29.8 |
| | Above Neutral | 3.1 | 13.5 | 5.4 | 1.6 | 3.7 | 1.8 | 3.6 | 0.2 | 4.0 |
| RLB/LLB | Mean | -3.4 | -4.1 | -3.5 | -6.2 | -6.0 | -7.3 | -6.5 | -8.0 | -5.6 |
| | Median | -3.6 | -3.6 | -3.3 | -5.8 | -5.7 | -7.4 | -6.2 | -8.6 | -5.3 |
| | Max | 6.4 | 6.3 | 5.3 | 6.1 | 5.5 | 4.6 | 2.7 | 4.9 | 6.3 |
| | Min | -14.8 | -19.5 | -21.9 | -28.0 | -23.9 | -17.7 | -22.4 | -21.9 | -28.0 |
| | ROM | 21.2 | 25.7 | 27.2 | 34.1 | 29.3 | 22.3 | 25.1 | 26.8 | 34.3 |
| | ISV | 3.2 | 4.6 | 3.5 | 4.2 | 4.2 | 3.4 | 4.1 | 4.0 | 4.2 |
| | Below Neutral | 0.0 | 0.0 | 0.2 | 1.0 | 0.3 | 0.0 | 0.4 | 0.6 | 0.4 |
| | Neutral | 100.0 | 100.0 | 99.8 | 99.0 | 99.7 | 100.0 | 99.6 | 99.4 | 99.6 |
| | Above Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| RAR/LAR | Mean | -5.3 | -2.9 | -1.1 | -2.7 | -1.8 | -2.0 | -2.4 | -1.8 | -2.1 |
| | Median | -5.0 | -2.5 | -0.9 | -2.5 | -1.6 | -1.9 | -2.5 | -1.9 | -1.9 |
| | Max | -0.2 | 6.5 | 6.2 | 3.7 | 12.7 | 4.4 | 12.4 | 23.6 | 23.6 |
| | Min | -13.4 | -13.7 | -12.4 | -11.0 | -17.6 | -11.1 | -11.9 | -9.2 | -17.6 |
| | ROM | 13.3 | 20.2 | 18.5 | 14.7 | 30.2 | 15.5 | 24.3 | 32.7 | 41.1 |
| | ISV | 3.0 | 3.4 | 2.8 | 2.6 | 3.3 | 2.6 | 2.8 | 3.0 | 3.2 |
| | Below Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Neutral | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 99.6 | 100.0 |
| | Above Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.0 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

## Appendix E.3: Conductor 3

Table E.3.1: Conductor 3, Neck.

| Rotation | Outcome Variable | Sample # 05 | 08 | 09 | 11 | 14 | 15 | Overall |
|---|---|---|---|---|---|---|---|---|
| F/E | Mean | -2.9 | -3.3 | 2.6 | 1.6 | -0.8 | -0.5 | -0.3 |
| | Median | -4.2 | -4.8 | -2.4 | 0.0 | -3.4 | -3.0 | -2.9 |
| | Max | 30.6 | 25.3 | 63.8 | 31.7 | 38.1 | 34.0 | 63.8 |
| | Min | -20.6 | -21.9 | -16.7 | -24.9 | -17.6 | -17.3 | -24.9 |
| | ROM | 51.2 | 47.2 | 80.4 | 56.6 | 55.7 | 51.3 | 88.7 |
| | ISV | 7.9 | 7.9 | 14.3 | 10.0 | 10.2 | 10.0 | 10.6 |
| | Below Neutral | 11.9 | 15.5 | 9.1 | 9.5 | 12.4 | 7.7 | 10.9 |
| | Neutral | 81.6 | 78.1 | 70.6 | 71.4 | 74.5 | 78.6 | 75.2 |
| | Above Neutral | 6.4 | 6.5 | 20.3 | 19.2 | 13.1 | 13.7 | 13.8 |
| RLB/LLB | Mean | 3.2 | 1.6 | 1.0 | 2.3 | 1.3 | 1.8 | 1.9 |
| | Median | 4.3 | 2.1 | 2.2 | 3.4 | 2.0 | 2.0 | 2.8 |
| | Max | 12.5 | 15.0 | 15.1 | 12.6 | 11.0 | 12.9 | 15.1 |
| | Min | -15.0 | -12.3 | -21.8 | -17.0 | -12.0 | -9.5 | -21.8 |
| | ROM | 27.5 | 27.4 | 36.9 | 29.6 | 22.9 | 22.4 | 36.9 |
| | ISV | 4.7 | 5.5 | 6.2 | 5.2 | 4.5 | 4.0 | 5.2 |
| | Below Neutral | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Neutral | 100.0 | 100.0 | 99.8 | 100.0 | 100.0 | 100.0 | 100.0 |
| | Above Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| RAR/LAR | Mean | 6.0 | 5.1 | 0.5 | 10.5 | 1.2 | 6.9 | 5.3 |
| | Median | 11.2 | 8.5 | 2.6 | 19.6 | 1.2 | 7.7 | 9.3 |
| | Max | 36.6 | 40.7 | 38.1 | 42.0 | 40.7 | 41.3 | 42.0 |
| | Min | -44.9 | -49.4 | -57.4 | -47.2 | -48.8 | -27.5 | -57.4 |
| | ROM | 81.5 | 90.1 | 95.5 | 89.2 | 89.4 | 68.8 | 99.3 |
| | ISV | 19.7 | 23.4 | 21.7 | 23.0 | 18.8 | 16.4 | 21.3 |
| | Below Neutral | 13.8 | 17.8 | 20.8 | 16.2 | 15.4 | 5.0 | 15.4 |
| | Neutral | 55.4 | 47.6 | 58.1 | 34.6 | 65.6 | 70.9 | 53.2 |
| | Above Neutral | 30.8 | 34.6 | 21.1 | 49.2 | 19.0 | 24.1 | 31.4 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

Table E.3.2: Conductor 3, Shoulder.

| Rotation | Outcome Variable | | Sample # 05 | 08 | 09 | 11 | 14 | 15 | Overall |
|---|---|---|---|---|---|---|---|---|---|
| F/E | Right | Mean | 22.8 | 13.8 | 11.2 | 19.7 | 16.8 | 24.4 | 18.0 |
| | | Median | 18.0 | 6.9 | 2.5 | 15.7 | 9.6 | 25.2 | 11.0 |
| | | Max | 103.8 | 108.3 | 138.7 | 131.6 | 101.2 | 78.6 | 104.5 |
| | | Min | -11.7 | -16.0 | -34.2 | -37.8 | -17.3 | -21.3 | -37.8 |
| | | ROM | 115.4 | 124.4 | 172.9 | 169.4 | 118.5 | 99.8 | 142.3 |
| | | ISV | 23.7 | 19.6 | 24.7 | 21.8 | 20.9 | 18.8 | 22.4 |
| | | Below Neutral | 0.0 | 0.0 | 2.9 | 1.1 | 0.0 | 0.1 | 0.8 |
| | | Neutral | 52.9 | 80.0 | 70.2 | 58.1 | 68.0 | 40.5 | 61.9 |
| | | Above Neutral | 47.1 | 20.0 | 26.9 | 40.8 | 32.0 | 59.4 | 37.4 |
| | Left | Mean | 50.2 | 32.1 | 31.0 | 43.8 | 36.5 | 41.3 | 39.7 |
| | | Median | 47.2 | 28.2 | 29.5 | 42.8 | 34.6 | 41.6 | 38.8 |
| | | Max | 95.6 | 105.3 | 119.3 | 90.7 | 91.4 | 97.7 | 119.3 |
| | | Min | -5.8 | -22.3 | -29.8 | -38.7 | -23.4 | -35.8 | -38.7 |
| | | ROM | 101.3 | 127.6 | 149.0 | 129.4 | 114.8 | 133.5 | 158.0 |
| | | ISV | 15.7 | 18.3 | 25.8 | 17.2 | 18.3 | 17.3 | 20.2 |
| | | Below Neutral | 0.0 | 0.1 | 7.6 | 1.0 | 0.6 | 1.3 | 1.8 |
| | | Neutral | 0.8 | 23.0 | 20.0 | 2.7 | 10.1 | 7.3 | 10.4 |
| | | Above Neutral | 99.2 | 76.8 | 72.4 | 96.3 | 89.2 | 91.4 | 87.8 |
| ABD/ ADD | Right | Mean | 26.2 | 24.6 | 20.9 | 26.1 | 24.8 | 26.5 | 24.9 |
| | | Median | 22.7 | 24.2 | 17.9 | 24.8 | 20.7 | 23.1 | 22.4 |
| | | Max | 65.1 | 64.2 | 61.8 | 64.1 | 72.2 | 59.4 | 72.2 |
| | | Min | 6.4 | 7.1 | -0.4 | 0.3 | 2.3 | 4.1 | -0.4 |
| | | ROM | 58.7 | 57.2 | 62.3 | 63.9 | 69.9 | 55.3 | 72.7 |
| | | ISV | 11.6 | 7.1 | 11.5 | 10.1 | 11.8 | 12.4 | 11.0 |
| | | Below Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Neutral | 40.7 | 22.9 | 58.1 | 34.9 | 46.3 | 38.6 | 40.9 |
| | | Above Neutral | 59.3 | 77.1 | 41.9 | 65.1 | 53.7 | 61.4 | 59.1 |
| | Left | Mean | 23.3 | 26.2 | 23.5 | 30.7 | 30.4 | 30.5 | 27.5 |
| | | Median | 21.4 | 24.7 | 24.7 | 30.5 | 30.1 | 31.1 | 27.4 |
| | | Max | 59.0 | 66.1 | 54.2 | 71.2 | 63.7 | 63.1 | 71.2 |
| | | Min | 1.4 | -4.0 | -10.6 | 2.6 | -0.9 | -1.2 | -10.6 |
| | | ROM | 57.6 | 70.1 | 64.8 | 68.7 | 64.6 | 64.3 | 81.8 |
| | | ISV | 10.7 | 8.9 | 13.7 | 9.4 | 12.3 | 10.9 | 11.6 |
| | | Below Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Neutral | 45.0 | 23.7 | 34.6 | 12.0 | 21.9 | 17.9 | 26.1 |
| | | Above Neutral | 55.0 | 76.3 | 65.4 | 88.0 | 78.1 | 82.1 | 74.0 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| IR/ER | Right | Mean | 0.1 | -5.6 | -5.2 | 0.0 | -3.7 | 5.5 | -1.7 |
| | | Median | -2.9 | -10.1 | -9.8 | -5.1 | -9.5 | 4.9 | -6.7 |
| | | Max | 90.7 | 115.1 | 109.5 | 106.1 | 94.5 | 61.0 | 66.9 |
| | | Min | -35.0 | -48.1 | -45.1 | -43.8 | -37.0 | -51.0 | -51.0 |
| | | ROM | 125.7 | 163.2 | 154.6 | 150.0 | 131.4 | 112.0 | 117.9 |
| | | ISV | 19.0 | 17.0 | 18.8 | 16.8 | 17.0 | 15.6 | 17.8 |
| | | Below Neutral | 16.0 | 11.2 | 16.1 | 5.0 | 12.3 | 2.8 | 10.6 |
| | | Neutral | 67.0 | 78.7 | 73.7 | 82.6 | 76.6 | 79.6 | 76.6 |
| | | Above Neutral | 17.0 | 10.1 | 10.1 | 12.4 | 11.1 | 17.6 | 12.8 |
| | Left | Mean | 26.9 | 9.3 | 12.3 | 18.0 | 16.0 | 20.1 | 17.3 |
| | | Median | 26.4 | 6.7 | 10.1 | 17.6 | 15.5 | 19.5 | 17.1 |
| | | Max | 72.7 | 76.9 | 84.2 | 77.6 | 86.8 | 74.6 | 86.8 |
| | | Min | -17.9 | -24.4 | -30.1 | -34.4 | -21.7 | -26.3 | -34.4 |
| | | ROM | 90.6 | 101.2 | 114.4 | 112.0 | 108.5 | 100.9 | 121.2 |
| | | ISV | 11.5 | 14.7 | 17.2 | 12.9 | 13.9 | 13.7 | 15.0 |
| | | Below Neutral | 0.0 | 0.2 | 1.0 | 0.1 | 0.1 | 0.3 | 0.3 |
| | | Neutral | 25.4 | 82.6 | 67.8 | 57.8 | 62.2 | 52.0 | 57.4 |
| | | Above Neutral | 74.6 | 17.2 | 31.2 | 42.2 | 37.7 | 47.7 | 42.3 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

Table E.3.3: Conductor 3, Elbow.

| Rotation | | Outcome Variable | Sample # 05 | 08 | 09 | 11 | 14 | 15 | Overall |
|---|---|---|---|---|---|---|---|---|---|
| F/E | Right | Mean | 63.7 | 83.2 | 48.9 | 61.6 | 61.7 | 66.3 | 63.1 |
| | | Median | 68.2 | 94.8 | 38.4 | 71.0 | 70.1 | 72.5 | 71.0 |
| | | Max | 150.3 | 149.2 | 151.7 | 151.8 | 138.0 | 141.5 | 144.0 |
| | | Min | -8.4 | -9.2 | -17.6 | -7.8 | -1.6 | -1.1 | -17.6 |
| | | ROM | 158.7 | 158.4 | 169.3 | 159.5 | 139.5 | 142.6 | 161.6 |
| | | ISV | 32.6 | 37.5 | 40.5 | 34.0 | 36.0 | 31.0 | 36.7 |
| | | Below Neutral | 41.9 | 25.6 | 57.8 | 40.1 | 0.0 | 35.2 | 41.4 |
| | | Neutral | 45.1 | 30.8 | 28.9 | 47.5 | 4.5 | 53.3 | 41.5 |
| | | Above Neutral | 13.0 | 43.7 | 13.3 | 12.5 | 95.6 | 11.5 | 17.1 |
| | Left | Mean | 71.5 | 86.8 | 75.0 | 74.9 | 75.7 | 69.8 | 75.4 |
| | | Median | 69.8 | 92.3 | 83.5 | 73.8 | 76.1 | 69.1 | 75.8 |
| | | Max | 136.0 | 152.8 | 137.9 | 134.0 | 135.0 | 135.7 | 152.8 |
| | | Min | 0.6 | -19.0 | -20.1 | -21.6 | -19.8 | -16.5 | -21.6 |
| | | ROM | 135.4 | 171.8 | 157.9 | 155.6 | 154.8 | 152.2 | 174.4 |
| | | ISV | 20.4 | 29.4 | 38.5 | 19.6 | 21.7 | 23.6 | 26.4 |
| | | Below Neutral | 27.1 | 17.1 | 25.3 | 20.7 | 0.0 | 30.9 | 23.1 |
| | | Neutral | 63.9 | 43.7 | 46.4 | 68.4 | 0.7 | 60.7 | 59.7 |
| | | Above Neutral | 9.0 | 39.1 | 28.4 | 10.9 | 99.3 | 8.4 | 17.2 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

Table E.3.4: Conductor 3, Wrist.

| Rotation | Outcome Variable | | Sample # 05 | 08 | 09 | 11 | 14 | 15 | Overall |
|---|---|---|---|---|---|---|---|---|---|
| F/E | Right | Mean | -8.6 | -9.2 | -13.5 | -6.9 | -6.5 | -5.2 | -8.4 |
| | | Median | -7.8 | -7.3 | -11.0 | -6.7 | -5.9 | -5.1 | -7.5 |
| | | Max | 47.1 | 46.5 | 78.1 | 50.5 | 50.6 | 44.4 | 31.9 |
| | | Min | -27.3 | -35.3 | -46.1 | -26.5 | -32.5 | -29.4 | -46.1 |
| | | ROM | 74.4 | 81.7 | 124.2 | 77.0 | 83.0 | 73.7 | 78.1 |
| | | ISV | 5.9 | 7.8 | 11.6 | 6.9 | 7.6 | 7.3 | 8.4 |
| | | Below Neutral | 79.6 | 71.7 | 91.0 | 63.4 | 42.5 | 51.8 | 69.5 |
| | | Neutral | 18.4 | 27.7 | 5.1 | 31.6 | 42.4 | 39.0 | 26.1 |
| | | Above Neutral | 2.1 | 0.6 | 4.0 | 5.0 | 15.1 | 9.2 | 4.5 |
| | Left | Mean | -9.8 | -8.4 | -13.9 | -10.4 | -11.7 | -11.9 | -11.0 |
| | | Median | -10.8 | -7.8 | -11.7 | -11.1 | -12.4 | -12.7 | -11.1 |
| | | Max | 19.7 | 30.2 | 37.0 | 16.9 | 40.3 | 23.4 | 40.3 |
| | | Min | -30.5 | -46.4 | -48.7 | -38.9 | -40.3 | -42.2 | -48.7 |
| | | ROM | 50.2 | 76.6 | 85.6 | 55.8 | 80.7 | 65.6 | 89.0 |
| | | ISV | 6.7 | 11.4 | 13.4 | 6.9 | 9.4 | 8.7 | 9.6 |
| | | Below Neutral | 79.9 | 63.3 | 73.6 | 79.8 | 19.7 | 82.5 | 77.0 |
| | | Neutral | 16.9 | 26.1 | 22.0 | 17.9 | 67.8 | 13.8 | 18.6 |
| | | Above Neutral | 3.2 | 10.6 | 4.4 | 2.3 | 12.5 | 3.8 | 4.4 |
| RD/UD | Right | Mean | -6.5 | 2.9 | 1.8 | -5.7 | -3.5 | -5.1 | -3.0 |
| | | Median | -6.2 | 2.4 | -0.2 | -5.7 | -4.1 | -5.8 | -3.4 |
| | | Max | 56.3 | 45.3 | 61.4 | 50.0 | 45.6 | 49.1 | 26.0 |
| | | Min | -41.0 | -21.6 | -35.4 | -29.3 | -26.1 | -31.5 | -41.0 |
| | | ROM | 97.2 | 67.0 | 96.7 | 79.3 | 71.7 | 80.6 | 66.9 |
| | | ISV | 7.0 | 6.0 | 10.4 | 7.3 | 8.4 | 7.5 | 8.7 |
| | | Below Neutral | 60.4 | 5.4 | 14.5 | 55.1 | 55.5 | 56.0 | 41.1 |
| | | Neutral | 36.0 | 60.6 | 52.5 | 38.7 | 37.7 | 34.0 | 42.7 |
| | | Above Neutral | 3.7 | 34.0 | 33.0 | 6.3 | 6.9 | 10.0 | 16.2 |
| | Left | Mean | -5.2 | 2.1 | 2.9 | -5.1 | -3.3 | -4.2 | -2.4 |
| | | Median | -4.6 | 3.5 | 4.4 | -4.5 | -2.7 | -3.8 | -1.9 |
| | | Max | 10.3 | 15.3 | 18.5 | 14.7 | 16.0 | 18.0 | 18.5 |
| | | Min | -31.8 | -26.1 | -33.4 | -26.8 | -32.3 | -37.9 | -37.9 |
| | | ROM | 42.1 | 41.4 | 52.0 | 41.5 | 48.3 | 55.9 | 56.4 |
| | | ISV | 6.2 | 6.3 | 7.4 | 6.4 | 7.9 | 7.7 | 7.7 |
| | | Below Neutral | 47.8 | 13.0 | 15.2 | 47.0 | 80.3 | 44.8 | 35.7 |
| | | Neutral | 50.3 | 49.7 | 39.4 | 48.8 | 15.5 | 45.7 | 47.0 |
| | | Above Neutral | 1.9 | 37.3 | 45.4 | 4.2 | 4.2 | 9.6 | 17.3 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| P/S | Right | Mean | 79.6 | 52.6 | 64.2 | 80.6 | 77.4 | 71.6 | 72.5 |
| | | Median | 90.1 | 51.2 | 75.8 | 87.4 | 83.6 | 78.6 | 80.4 |
| | | Max | 146.8 | 171.3 | 165.0 | 159.3 | 141.0 | 144.1 | 145.9 |
| | | Min | -9.6 | -25.4 | -28.2 | -14.2 | -4.7 | -17.1 | -28.2 |
| | | ROM | 156.4 | 196.7 | 193.2 | 173.4 | 145.7 | 161.2 | 174.0 |
| | | ISV | 32.5 | 30.0 | 28.3 | 28.4 | 25.9 | 30.8 | 30.7 |
| | | Below Neutral | 0.0 | 0.2 | 0.1 | 0.0 | 45.4 | 0.0 | 0.0 |
| | | Neutral | 5.6 | 14.7 | 12.5 | 6.0 | 37.8 | 9.3 | 8.3 |
| | | Above Neutral | 94.4 | 85.1 | 87.5 | 94.0 | 16.9 | 90.7 | 91.6 |
| | Left | Mean | 87.9 | 56.9 | 66.5 | 88.8 | 82.1 | 82.4 | 76.7 |
| | | Median | 90.3 | 60.9 | 71.4 | 90.7 | 83.9 | 85.2 | 80.8 |
| | | Max | 129.5 | 141.2 | 142.0 | 151.9 | 137.6 | 134.8 | 143.8 |
| | | Min | -2.7 | -15.8 | -3.6 | 12.3 | -3.2 | -6.9 | -18.7 |
| | | ROM | 132.3 | 157.0 | 145.6 | 139.7 | 140.8 | 141.8 | 162.6 |
| | | ISV | 20.0 | 27.7 | 27.3 | 18.6 | 19.4 | 20.4 | 26.0 |
| | | Below Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 39.1 | 0.0 | 0.0 |
| | | Neutral | 0.6 | 12.2 | 8.8 | 0.0 | 47.7 | 0.8 | 4.6 |
| | | Above Neutral | 99.4 | 87.8 | 91.2 | 100.0 | 13.2 | 99.3 | 95.4 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

Table E.3.5: Conductor 3, Trunk.

| Rotation | Outcome Variable | Sample # 05 | 08 | 09 | 11 | 14 | 15 | Overall |
|---|---|---|---|---|---|---|---|---|
| F/E | Mean | -3.1 | -6.9 | -3.2 | -1.6 | -0.2 | -0.5 | -2.5 |
| | Median | -3.6 | -7.8 | -5.4 | -1.8 | -0.4 | -1.0 | -3.1 |
| | Max | 9.0 | 18.4 | 24.9 | 13.7 | 16.5 | 15.5 | 24.9 |
| | Min | -12.4 | -18.8 | -35.1 | -16.7 | -16.1 | -12.2 | -35.1 |
| | ROM | 21.4 | 37.2 | 60.0 | 30.4 | 32.6 | 27.7 | 60.0 |
| | ISV | 4.3 | 4.8 | 7.3 | 4.4 | 5.3 | 6.4 | 5.8 |
| | Below Neutral | 35.6 | 75.3 | 52.3 | 19.5 | 15.8 | 25.7 | 35.2 |
| | Neutral | 59.3 | 20.3 | 34.6 | 73.9 | 70.2 | 52.9 | 54.7 |
| | Above Neutral | 5.1 | 4.5 | 13.1 | 6.6 | 14.0 | 21.4 | 10.1 |
| RLB/LLB | Mean | 1.9 | 3.4 | 3.7 | 1.1 | 1.1 | 0.3 | 1.9 |
| | Median | 1.8 | 3.7 | 2.7 | 1.3 | 0.8 | 0.7 | 1.6 |
| | Max | 8.8 | 14.9 | 15.0 | 9.8 | 12.5 | 7.0 | 15.0 |
| | Min | -4.4 | -8.2 | -13.0 | -8.4 | -6.1 | -13.0 | -13.0 |
| | ROM | 13.2 | 23.1 | 28.0 | 18.2 | 18.5 | 20.0 | 28.0 |
| | ISV | 2.4 | 3.7 | 4.3 | 2.6 | 2.6 | 2.9 | 3.3 |
| | Below Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Neutral | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| | Above Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| RAR/LAR | Mean | -0.4 | 0.4 | -0.7 | -0.4 | -0.2 | -0.7 | -0.3 |
| | Median | -0.1 | 0.5 | 0.0 | -0.1 | -0.2 | -0.3 | -0.1 |
| | Max | 11.2 | 9.9 | 12.7 | 9.9 | 11.4 | 7.5 | 12.7 |
| | Min | -10.7 | -14.0 | -13.9 | -11.3 | -10.6 | -9.6 | -14.0 |
| | ROM | 21.9 | 23.8 | 26.6 | 21.2 | 21.9 | 17.1 | 26.7 |
| | ISV | 3.2 | 2.9 | 3.9 | 3.3 | 3.1 | 2.9 | 3.3 |
| | Below Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Neutral | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| | Above Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

## Appendix E.4: Conductor 4

Table E.4.1: Conductor 4, Neck.

| Rotation | Outcome Variable | Sample # 02 | 03 | 04 | 05 | 06 | 07 | 08 | Overall |
|---|---|---|---|---|---|---|---|---|---|
| F/E | Mean | 16.1 | 15.4 | 17.2 | 18.2 | 20.7 | 18.1 | 17.8 | 18.0 |
| | Median | 19.3 | 16.8 | 19.9 | 20.6 | 22.0 | 19.6 | 20.6 | 20.2 |
| | Max | 49.6 | 51.1 | 34.3 | 60.1 | 37.4 | 49.9 | 44.5 | 60.1 |
| | Min | -22.9 | -19.7 | -23.6 | -21.4 | -15.1 | -20.2 | -16.7 | -23.6 |
| | ROM | 72.5 | 70.8 | 57.9 | 81.6 | 52.5 | 70.0 | 61.2 | 83.7 |
| | ISV | 10.7 | 8.7 | 10.2 | 11.4 | 7.5 | 8.2 | 10.0 | 10.1 |
| | Below Neutral | 3.3 | 1.7 | 3.6 | 3.6 | 0.5 | 1.5 | 2.6 | 2.6 |
| | Neutral | 16.9 | 18.6 | 13.6 | 13.4 | 6.7 | 9.9 | 14.2 | 12.9 |
| | Above Neutral | 79.8 | 79.7 | 82.8 | 83.0 | 92.8 | 88.6 | 83.2 | 84.5 |
| RLB/LLB | Mean | -6.6 | -8.7 | -8.4 | -9.8 | -10.0 | -9.3 | -9.8 | -9.1 |
| | Median | -6.7 | -9.3 | -8.6 | -9.6 | -10.4 | -9.6 | -10.0 | -9.2 |
| | Max | 9.0 | 5.0 | 2.7 | 5.3 | 3.6 | 7.1 | 3.9 | 9.0 |
| | Min | -20.4 | -22.5 | -19.9 | -32.8 | -22.4 | -24.3 | -21.7 | -32.8 |
| | ROM | 29.4 | 27.5 | 22.6 | 38.1 | 26.0 | 31.4 | 25.6 | 41.8 |
| | ISV | 4.4 | 5.0 | 4.1 | 4.9 | 4.3 | 4.1 | 4.3 | 4.7 |
| | Below Neutral | 0.0 | 1.1 | 0.0 | 2.0 | 0.2 | 0.4 | 0.9 | 1.0 |
| | Neutral | 100.0 | 98.9 | 100.0 | 98.0 | 99.8 | 99.6 | 99.1 | 99.1 |
| | Above Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| RAR/LAR | Mean | 15.2 | 18.0 | 15.3 | 13.1 | 13.0 | 13.8 | 12.1 | 13.9 |
| | Median | 15.0 | 18.3 | 14.6 | 12.9 | 13.1 | 13.7 | 12.4 | 13.8 |
| | Max | 47.0 | 49.5 | 42.1 | 44.8 | 42.9 | 44.0 | 35.1 | 49.5 |
| | Min | -30.5 | -26.8 | -15.9 | -30.3 | -29.3 | -27.4 | -20.6 | -30.5 |
| | ROM | 77.5 | 76.3 | 57.9 | 75.1 | 72.2 | 71.4 | 55.7 | 80.0 |
| | ISV | 9.3 | 9.2 | 8.7 | 10.5 | 7.2 | 9.0 | 9.4 | 9.5 |
| | Below Neutral | 0.2 | 0.2 | 0.0 | 0.8 | 0.3 | 0.2 | 0.0 | 0.4 |
| | Neutral | 72.1 | 57.8 | 73.4 | 75.7 | 85.0 | 78.6 | 82.1 | 76.2 |
| | Above Neutral | 27.7 | 42.0 | 26.6 | 23.5 | 14.7 | 21.2 | 17.9 | 23.4 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

Table E.4.2: Conductor 4, Shoulder.

| Rotation | Outcome Variable | | Sample # 02 | 03 | 04 | 05 | 06 | 07 | 08 | Overall |
|---|---|---|---|---|---|---|---|---|---|---|
| F/E | Right | Mean | 52.1 | 51.3 | 56.0 | 50.6 | 53.8 | 39.4 | 53.5 | 50.5 |
| | | Median | 52.1 | 51.3 | 56.9 | 50.6 | 52.9 | 37.3 | 52.8 | 50.4 |
| | | Max | 121.1 | 107.7 | 106.1 | 113.5 | 108.7 | 131.4 | 112.5 | 127.6 |
| | | Min | -6.3 | -12.0 | 8.4 | -9.4 | 11.0 | -3.8 | -7.4 | -12.0 |
| | | ROM | 127.4 | 119.7 | 97.7 | 122.9 | 97.7 | 135.1 | 119.9 | 139.6 |
| | | ISV | 15.6 | 14.7 | 14.6 | 16.6 | 14.5 | 16.4 | 15.1 | 16.4 |
| | | Below Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Neutral | 1.9 | 2.1 | 0.8 | 3.2 | 0.5 | 9.2 | 1.0 | 3.0 |
| | | Above Neutral | 98.1 | 97.9 | 99.2 | 96.8 | 99.6 | 90.8 | 99.0 | 97.1 |
| | Left | Mean | 25.8 | 27.9 | 24.3 | 27.6 | 28.5 | 14.6 | 32.2 | 26.0 |
| | | Median | 23.3 | 26.3 | 17.7 | 25.3 | 25.5 | 3.6 | 30.8 | 22.7 |
| | | Max | 100.7 | 103.8 | 93.9 | 102.6 | 97.4 | 89.1 | 86.7 | 103.8 |
| | | Min | -19.7 | -31.4 | -12.2 | -21.1 | -18.5 | -33.1 | -21.4 | -33.1 |
| | | ROM | 120.4 | 135.2 | 106.1 | 123.7 | 115.8 | 122.2 | 108.1 | 136.9 |
| | | ISV | 23.0 | 22.1 | 24.4 | 24.8 | 23.9 | 21.2 | 22.8 | 24.1 |
| | | Below Neutral | 0.0 | 0.3 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 |
| | | Neutral | 45.6 | 39.1 | 52.5 | 43.7 | 44.1 | 68.6 | 32.8 | 46.7 |
| | | Above Neutral | 54.4 | 60.6 | 47.5 | 56.3 | 55.9 | 31.3 | 67.1 | 53.3 |
| ABD/ADD | Right | Mean | 28.3 | 22.6 | 22.5 | 24.8 | 25.4 | 27.4 | 23.3 | 25.2 |
| | | Median | 28.4 | 22.4 | 22.5 | 24.9 | 23.2 | 27.9 | 21.7 | 25.0 |
| | | Max | 95.6 | 69.1 | 68.8 | 65.2 | 61.7 | 110.7 | 84.7 | 65.2 |
| | | Min | -30.9 | -9.5 | -15.1 | -22.4 | -8.3 | -46.1 | -27.4 | -46.1 |
| | | ROM | 126.5 | 78.6 | 83.9 | 87.6 | 69.9 | 156.7 | 112.1 | 111.3 |
| | | ISV | 11.3 | 9.5 | 11.9 | 12.2 | 11.6 | 10.1 | 12.2 | 11.7 |
| | | Below Neutral | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.2 | 0.1 |
| | | Neutral | 21.7 | 39.1 | 40.5 | 34.0 | 36.9 | 16.9 | 43.6 | 32.2 |
| | | Above Neutral | 78.2 | 60.9 | 59.5 | 66.0 | 63.2 | 82.8 | 56.2 | 67.7 |
| | Left | Mean | 23.7 | 22.6 | 23.7 | 25.2 | 26.1 | 19.5 | 26.3 | 24.2 |
| | | Median | 19.7 | 18.5 | 18.8 | 21.4 | 23.2 | 14.8 | 23.7 | 20.2 |
| | | Max | 69.1 | 66.2 | 71.0 | 75.5 | 69.9 | 77.6 | 67.6 | 77.6 |
| | | Min | -4.3 | -5.5 | -3.8 | -8.3 | 2.5 | -7.6 | -3.2 | -8.3 |
| | | ROM | 73.4 | 71.7 | 74.8 | 83.9 | 67.4 | 85.2 | 70.9 | 85.9 |
| | | ISV | 12.8 | 13.2 | 12.7 | 13.7 | 12.8 | 11.6 | 13.7 | 13.3 |
| | | Below Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Neutral | 50.9 | 53.4 | 53.8 | 46.7 | 41.9 | 66.8 | 40.0 | 49.6 |
| | | Above Neutral | 49.1 | 46.6 | 46.2 | 53.4 | 58.1 | 33.2 | 60.0 | 50.4 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| IR/ER | Right | Mean | 18.6 | 22.0 | 22.6 | 18.8 | 21.4 | 13.8 | 21.8 | 19.3 |
| | | Median | 18.3 | 21.4 | 21.9 | 18.2 | 20.8 | 13.3 | 20.6 | 18.8 |
| | | Max | 87.6 | 72.1 | 78.2 | 63.4 | 59.6 | 97.5 | 82.4 | 72.5 |
| | | Min | -24.9 | -14.7 | -17.5 | -32.3 | -17.7 | -25.1 | -16.2 | -32.3 |
| | | ROM | 112.5 | 86.9 | 95.7 | 95.7 | 77.3 | 122.6 | 98.6 | 104.8 |
| | | ISV | 13.0 | 11.3 | 11.8 | 12.7 | 12.0 | 12.1 | 12.2 | 12.6 |
| | | Below Neutral | 0.1 | 0.0 | 0.0 | 0.1 | 0.0 | 0.1 | 0.0 | 0.1 |
| | | Neutral | 55.3 | 44.5 | 42.9 | 55.8 | 47.7 | 70.9 | 47.4 | 54.0 |
| | | Above Neutral | 44.6 | 55.5 | 57.1 | 44.2 | 52.3 | 29.1 | 52.6 | 45.9 |
| | Left | Mean | 3.2 | 5.5 | 0.5 | 2.2 | 4.3 | -4.1 | 6.4 | 2.3 |
| | | Median | 2.3 | 4.2 | -1.3 | 0.8 | 2.9 | -5.5 | 7.1 | 0.5 |
| | | Max | 49.1 | 56.3 | 54.2 | 71.3 | 53.1 | 41.7 | 49.0 | 71.3 |
| | | Min | -36.3 | -39.0 | -31.6 | -49.7 | -30.1 | -45.6 | -38.4 | -49.7 |
| | | ROM | 85.4 | 95.2 | 85.7 | 121.0 | 83.2 | 87.3 | 87.4 | 121.0 |
| | | ISV | 13.4 | 14.4 | 13.1 | 15.0 | 13.6 | 11.7 | 15.1 | 14.3 |
| | | Below Neutral | 2.9 | 2.7 | 2.6 | 4.4 | 0.8 | 5.2 | 3.5 | 3.4 |
| | | Neutral | 84.8 | 80.1 | 89.2 | 81.8 | 86.0 | 90.4 | 76.5 | 83.9 |
| | | Above Neutral | 12.3 | 17.2 | 8.2 | 13.9 | 13.2 | 4.4 | 20.0 | 12.7 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

Table E.4.3: Conductor 4, Elbow.

| Rotation | Outcome Variable | | Sample # 02 | 03 | 04 | 05 | 06 | 07 | 08 | Overall |
|---|---|---|---|---|---|---|---|---|---|---|
| F/E | Right | Mean | 73.1 | 77.7 | 61.7 | 65.0 | 61.1 | 76.6 | 54.8 | 66.7 |
| | | Median | 74.2 | 79.4 | 60.8 | 64.8 | 62.2 | 77.4 | 53.5 | 67.2 |
| | | Max | 141.3 | 131.6 | 117.3 | 133.3 | 127.8 | 131.0 | 127.1 | 133.3 |
| | | Min | -8.5 | -3.1 | 5.6 | -10.1 | -0.2 | 4.6 | -5.7 | -10.1 |
| | | ROM | 149.8 | 134.7 | 111.8 | 143.4 | 127.9 | 126.4 | 132.8 | 143.4 |
| | | ISV | 20.9 | 20.4 | 17.2 | 22.2 | 21.8 | 18.6 | 22.0 | 22.1 |
| | | Below Neutral | 27.2 | 19.4 | 48.1 | 41.6 | 46.2 | 16.8 | 61.4 | 38.0 |
| | | Neutral | 63.8 | 67.9 | 50.0 | 52.4 | 50.6 | 74.0 | 35.6 | 55.8 |
| | | Above Neutral | 9.0 | 12.7 | 1.9 | 6.0 | 3.3 | 9.2 | 3.0 | 6.3 |
| | Left | Mean | 45.8 | 54.1 | 37.1 | 44.5 | 41.8 | 30.8 | 50.9 | 43.1 |
| | | Median | 37.4 | 53.3 | 29.3 | 35.0 | 33.5 | 20.1 | 45.7 | 33.5 |
| | | Max | 136.1 | 132.0 | 129.8 | 145.6 | 140.4 | 149.6 | 149.7 | 149.7 |
| | | Min | -3.2 | -1.7 | -1.8 | -7.9 | -3.9 | -5.8 | -4.8 | -7.9 |
| | | ROM | 139.3 | 133.7 | 131.5 | 153.6 | 144.3 | 155.4 | 154.5 | 157.6 |
| | | ISV | 33.3 | 31.9 | 27.0 | 33.5 | 32.4 | 27.5 | 36.9 | 32.9 |
| | | Below Neutral | 64.6 | 54.4 | 80.0 | 68.9 | 70.0 | 82.5 | 61.0 | 69.5 |
| | | Neutral | 27.9 | 38.1 | 17.5 | 23.0 | 25.2 | 15.5 | 24.9 | 23.7 |
| | | Above Neutral | 7.5 | 7.5 | 2.4 | 8.1 | 4.7 | 2.1 | 14.1 | 6.8 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

Table E.4.4: Conductor 4, Wrist.

| Rotation | Outcome Variable | | Sample # | | | | | | | Overall |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 02 | 03 | 04 | 05 | 06 | 07 | 08 | |
| F/E | Right | Mean | -3.4 | -4.4 | -0.1 | 0.4 | 7.3 | -7.0 | 6.7 | 0.2 |
| | | Median | -5.5 | -6.1 | -1.5 | -1.4 | 7.6 | -7.9 | 5.3 | -1.7 |
| | | Max | 65.2 | 64.9 | 59.3 | 37.7 | 34.8 | 64.3 | 55.0 | 37.7 |
| | | Min | -28.2 | -30.4 | -24.9 | -30.8 | -17.4 | -29.9 | -20.0 | -30.8 |
| | | ROM | 93.4 | 95.3 | 84.2 | 68.5 | 52.2 | 94.2 | 75.0 | 68.5 |
| | | ISV | 9.7 | 9.6 | 9.4 | 10.8 | 8.5 | 7.4 | 10.8 | 10.8 |
| | | Below Neutral | 52.0 | 54.9 | 32.2 | 34.8 | 6.6 | 67.5 | 14.0 | 36.5 |
| | | Neutral | 26.8 | 29.0 | 40.6 | 34.6 | 34.6 | 26.3 | 35.1 | 32.6 |
| | | Above Neutral | 21.2 | 16.1 | 27.3 | 30.6 | 58.8 | 6.2 | 51.0 | 30.9 |
| | Left | Mean | -3.2 | -2.6 | -6.5 | -0.4 | 3.8 | -6.4 | 4.5 | -1.1 |
| | | Median | -1.2 | -0.3 | -4.3 | 0.1 | 4.7 | -4.8 | 6.2 | -0.8 |
| | | Max | 23.7 | 20.6 | 21.2 | 34.3 | 27.1 | 20.9 | 33.8 | 34.3 |
| | | Min | -34.1 | -32.7 | -34.3 | -33.1 | -32.9 | -33.3 | -32.6 | -34.3 |
| | | ROM | 57.7 | 53.2 | 55.5 | 67.3 | 59.9 | 54.2 | 66.3 | 68.5 |
| | | ISV | 10.6 | 10.2 | 8.8 | 12.2 | 11.0 | 8.2 | 11.7 | 11.5 |
| | | Below Neutral | 33.8 | 33.7 | 44.5 | 29.7 | 13.6 | 48.3 | 13.8 | 30.3 |
| | | Neutral | 46.2 | 44.1 | 49.8 | 39.0 | 37.9 | 45.3 | 31.6 | 41.1 |
| | | Above Neutral | 20.1 | 22.2 | 5.7 | 31.3 | 48.4 | 6.4 | 54.5 | 28.6 |
| RD/UD | Right | Mean | -5.3 | -3.7 | -4.6 | -5.4 | -7.8 | -7.1 | -6.6 | -5.9 |
| | | Median | -4.7 | -2.6 | -3.4 | -4.4 | -6.9 | -6.6 | -5.2 | -5.0 |
| | | Max | 66.0 | 59.9 | 59.5 | 26.6 | 16.5 | 65.0 | 61.4 | 26.6 |
| | | Min | -45.6 | -43.8 | -42.6 | -47.9 | -41.9 | -45.4 | -44.4 | -47.9 |
| | | ROM | 111.6 | 103.7 | 102.2 | 74.5 | 58.4 | 110.4 | 105.8 | 74.5 |
| | | ISV | 8.0 | 8.4 | 9.3 | 9.6 | 8.9 | 8.2 | 11.0 | 9.2 |
| | | Below Neutral | 48.5 | 37.1 | 43.0 | 47.0 | 58.8 | 58.7 | 50.8 | 49.8 |
| | | Neutral | 43.6 | 51.1 | 44.5 | 41.5 | 35.8 | 36.5 | 35.6 | 40.6 |
| | | Above Neutral | 7.9 | 11.8 | 12.5 | 11.5 | 5.4 | 4.8 | 13.6 | 9.6 |
| | Left | Mean | 3.0 | 3.1 | 3.6 | 0.0 | -2.0 | 1.7 | -1.3 | 0.7 |
| | | Median | 3.3 | 3.8 | 3.5 | 0.4 | -2.8 | 1.6 | -1.9 | 1.0 |
| | | Max | 33.2 | 32.6 | 32.8 | 36.6 | 30.0 | 35.4 | 35.8 | 36.6 |
| | | Min | -37.1 | -38.4 | -34.2 | -46.4 | -39.3 | -38.1 | -43.8 | -46.4 |
| | | ROM | 70.3 | 70.9 | 67.0 | 83.1 | 69.3 | 73.5 | 79.6 | 83.1 |
| | | ISV | 9.6 | 8.9 | 8.9 | 11.0 | 10.5 | 8.5 | 11.0 | 10.3 |
| | | Below Neutral | 17.2 | 17.4 | 13.5 | 27.7 | 35.9 | 16.7 | 33.5 | 24.8 |
| | | Neutral | 41.1 | 38.6 | 43.3 | 41.7 | 39.3 | 53.8 | 40.1 | 42.6 |
| | | Above Neutral | 41.7 | 44.1 | 43.2 | 30.7 | 24.8 | 29.5 | 26.4 | 32.6 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| P/S | Right | Mean | 54.9 | 50.0 | 59.3 | 55.5 | 62.6 | 51.3 | 59.1 | 56.2 |
| | | Median | 57.4 | 52.1 | 63.3 | 60.0 | 66.2 | 53.6 | 63.9 | 59.2 |
| | | Max | 158.3 | 154.8 | 147.5 | 128.9 | 137.7 | 141.6 | 158.4 | 137.7 |
| | | Min | -29.4 | -28.9 | -18.5 | -29.7 | -20.4 | -26.4 | -27.7 | -29.7 |
| | | ROM | 187.7 | 183.8 | 166.0 | 158.6 | 158.1 | 168.0 | 186.1 | 167.4 |
| | | ISV | 21.7 | 22.5 | 21.7 | 27.3 | 29.5 | 19.6 | 31.2 | 26.0 |
| | | Below Neutral | 0.2 | 0.4 | 0.0 | 0.3 | 0.0 | 0.0 | 0.4 | 0.2 |
| | | Neutral | 6.8 | 9.9 | 6.4 | 12.2 | 10.9 | 7.5 | 13.4 | 10.2 |
| | | Above Neutral | 93.1 | 89.8 | 93.6 | 87.6 | 89.1 | 92.5 | 86.2 | 89.7 |
| | Left | Mean | 74.3 | 66.1 | 78.3 | 65.0 | 74.1 | 84.6 | 55.6 | 70.4 |
| | | Median | 76.5 | 69.1 | 85.6 | 72.3 | 81.7 | 94.4 | 55.1 | 78.1 |
| | | Max | 164.8 | 137.9 | 137.1 | 172.4 | 130.9 | 166.2 | 143.3 | 172.4 |
| | | Min | -14.9 | -9.3 | -18.6 | -46.4 | -44.2 | -39.0 | -60.9 | -60.9 |
| | | ROM | 179.7 | 147.2 | 155.7 | 218.8 | 175.1 | 205.2 | 204.2 | 233.3 |
| | | ISV | 30.8 | 28.8 | 25.2 | 38.4 | 31.5 | 30.5 | 38.0 | 35.0 |
| | | Below Neutral | 0.0 | 0.0 | 0.0 | 1.2 | 0.2 | 0.5 | 1.8 | 0.7 |
| | | Neutral | 5.6 | 6.7 | 3.6 | 15.7 | 7.0 | 5.0 | 18.8 | 10.4 |
| | | Above Neutral | 94.4 | 93.3 | 96.4 | 83.1 | 92.8 | 94.6 | 79.4 | 88.9 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

Table E.4.5: Conductor 4, Trunk.

| Rotation | Outcome Variable | Sample # 02 | 03 | 04 | 05 | 06 | 07 | 08 | Overall |
|---|---|---|---|---|---|---|---|---|---|
| F/E | Mean | 13.3 | 17.7 | -5.3 | 10.3 | -0.5 | 5.1 | 1.5 | 6.9 |
| | Median | 12.6 | 17.7 | -5.1 | 10.0 | -1.3 | 5.2 | 0.1 | 7.3 |
| | Max | 36.7 | 34.2 | 5.1 | 34.7 | 27.5 | 27.9 | 30.4 | 36.7 |
| | Min | -6.9 | 0.0 | -13.6 | -15.7 | -19.7 | -15.7 | -21.3 | -21.3 |
| | ROM | 43.5 | 34.2 | 18.7 | 50.4 | 47.2 | 43.6 | 51.7 | 58.0 |
| | ISV | 6.2 | 6.1 | 2.2 | 6.8 | 6.3 | 6.4 | 7.9 | 9.0 |
| | Below Neutral | 0.1 | 0.0 | 52.1 | 1.4 | 20.3 | 5.7 | 16.4 | 9.8 |
| | Neutral | 5.6 | 2.0 | 47.9 | 19.0 | 64.9 | 42.8 | 56.9 | 31.6 |
| | Above Neutral | 94.4 | 98.0 | 0.0 | 79.7 | 14.9 | 51.5 | 26.8 | 58.7 |
| RLB/LLB | Mean | -0.1 | -1.7 | -0.4 | 3.4 | 6.6 | 8.6 | 8.3 | 3.9 |
| | Median | 1.3 | -0.5 | -0.1 | 4.2 | 7.2 | 10.8 | 9.6 | 4.2 |
| | Max | 15.3 | 16.8 | 13.3 | 24.1 | 26.1 | 24.6 | 29.7 | 29.7 |
| | Min | -18.9 | -23.5 | -21.3 | -19.5 | -12.1 | -17.4 | -12.0 | -23.5 |
| | ROM | 34.2 | 40.4 | 34.6 | 43.6 | 38.2 | 42.0 | 41.8 | 53.2 |
| | ISV | 6.4 | 6.6 | 4.3 | 6.7 | 6.6 | 7.6 | 7.5 | 7.5 |
| | Below Neutral | 0.0 | 0.4 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Neutral | 100.0 | 99.6 | 99.9 | 99.8 | 99.1 | 99.2 | 97.3 | 99.4 |
| | Above Neutral | 0.0 | 0.0 | 0.0 | 0.2 | 0.9 | 0.8 | 2.7 | 0.5 |
| RAR/LAR | Mean | -0.9 | -0.9 | 6.5 | -0.1 | 0.3 | 0.1 | 0.1 | 0.4 |
| | Median | -0.6 | -0.6 | 5.8 | 0.1 | 0.4 | 0.7 | 0.2 | 0.3 |
| | Max | 20.7 | 11.5 | 31.1 | 22.0 | 13.7 | 15.3 | 19.1 | 31.1 |
| | Min | -19.4 | -16.2 | -16.1 | -23.4 | -17.3 | -16.6 | -13.9 | -23.4 |
| | ROM | 40.1 | 27.7 | 47.2 | 45.4 | 30.9 | 31.9 | 33.1 | 54.5 |
| | ISV | 4.1 | 4.1 | 8.1 | 4.2 | 3.3 | 3.6 | 4.4 | 4.8 |
| | Below Neutral | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Neutral | 100.0 | 100.0 | 93.6 | 99.9 | 100.0 | 100.0 | 100.0 | 99.5 |
| | Above Neutral | 0.0 | 0.0 | 6.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

## Appendix E.5: Conductor 5

Table E.5.1: Conductor 5, Neck.

| Rotation | Outcome Variable | Sample # | | | | Overall |
|---|---|---|---|---|---|---|
| | | 02 | 07 | 08 | 09 | |
| F/E | Mean | 26.1 | 31.7 | 32.5 | 29.6 | 28.8 |
| | Median | 30.1 | 36.2 | 34.3 | 36.2 | 33.2 |
| | Max | 61.2 | 49.4 | 52.2 | 55.5 | 61.2 |
| | Min | -13.5 | -12.2 | -7.3 | -14.6 | -14.6 |
| | ROM | 74.7 | 61.7 | 59.5 | 70.1 | 75.8 |
| | ISV | 13.3 | 12.5 | 10.7 | 15.9 | 13.5 |
| | Below Neutral | 1.0 | 1.1 | 0.0 | 1.5 | 1.0 |
| | Neutral | 12.9 | 8.5 | 5.9 | 16.3 | 11.5 |
| | Above Neutral | 86.1 | 90.5 | 94.2 | 82.2 | 87.5 |
| RLB/LLB | Mean | -0.4 | -7.0 | -5.7 | -4.2 | -3.1 |
| | Median | -1.0 | -6.4 | -5.9 | -4.5 | -3.6 |
| | Max | 20.2 | 8.6 | 4.6 | 7.5 | 20.2 |
| | Min | -19.6 | -35.6 | -21.5 | -17.3 | -35.6 |
| | ROM | 39.8 | 44.1 | 26.1 | 24.8 | 55.8 |
| | ISV | 5.8 | 4.8 | 4.2 | 4.7 | 5.9 |
| | Below Neutral | 0.0 | 0.9 | 0.2 | 0.0 | 0.2 |
| | Neutral | 99.9 | 99.1 | 99.8 | 100.0 | 99.8 |
| | Above Neutral | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| RAR/LAR | Mean | -14.4 | 4.5 | -3.5 | -0.8 | -6.6 |
| | Median | -15.7 | 2.5 | -6.3 | 1.0 | -7.0 |
| | Max | 30.6 | 43.5 | 37.4 | 37.7 | 43.5 |
| | Min | -52.0 | -51.4 | -50.1 | -52.1 | -52.1 |
| | ROM | 82.6 | 95.0 | 87.5 | 89.9 | 95.7 |
| | ISV | 14.5 | 16.0 | 14.9 | 16.9 | 17.2 |
| | Below Neutral | 36.6 | 4.6 | 6.7 | 15.2 | 22.0 |
| | Neutral | 61.1 | 78.8 | 85.9 | 74.3 | 70.6 |
| | Above Neutral | 2.3 | 16.6 | 7.4 | 10.4 | 7.4 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

Table E.5.2: Conductor 5, Shoulder.

| Rotation | Outcome Variable | | Sample # 02 | 07 | 08 | 09 | Overall |
|---|---|---|---|---|---|---|---|
| F/E | Right | Mean | 66.2 | 28.1 | 42.6 | 42.6 | 50.9 |
| | | Median | 65.2 | 26.4 | 42.8 | 41.2 | 50.8 |
| | | Max | 104.2 | 131.2 | 86.5 | 87.1 | 105.8 |
| | | Min | 3.1 | -25.4 | 1.3 | -1.9 | -25.4 |
| | | ROM | 101.1 | 156.6 | 85.1 | 89.3 | 131.2 |
| | | ISV | 16.2 | 16.0 | 14.2 | 15.2 | 22.1 |
| | | Below Neutral | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 |
| | | Neutral | 0.6 | 33.2 | 6.7 | 5.5 | 9.0 |
| | | Above Neutral | 99.5 | 66.7 | 93.3 | 94.5 | 90.9 |
| | Left | Mean | 44.5 | 20.8 | 26.1 | 34.5 | 35.2 |
| | | Median | 39.9 | 21.6 | 25.5 | 34.4 | 31.9 |
| | | Max | 103.6 | 82.9 | 83.3 | 85.4 | 103.6 |
| | | Min | -15.6 | -28.8 | -7.8 | -20.2 | -28.8 |
| | | ROM | 119.3 | 111.7 | 91.1 | 105.6 | 132.5 |
| | | ISV | 24.9 | 16.0 | 16.5 | 20.0 | 23.5 |
| | | Below Neutral | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 |
| | | Neutral | 18.6 | 46.2 | 37.5 | 26.5 | 28.4 |
| | | Above Neutral | 81.4 | 53.7 | 62.5 | 73.5 | 71.6 |
| ABD/ADD | Right | Mean | 20.7 | 21.5 | 17.4 | 17.0 | 19.8 |
| | | Median | 20.7 | 22.1 | 18.7 | 16.9 | 19.8 |
| | | Max | 64.1 | 56.2 | 65.0 | 70.8 | 56.2 |
| | | Min | -9.0 | 0.9 | -9.2 | -22.2 | -22.2 |
| | | ROM | 73.1 | 55.4 | 74.2 | 93.0 | 78.4 |
| | | ISV | 10.8 | 7.7 | 9.6 | 8.1 | 9.8 |
| | | Below Neutral | 0.0 | 0.0 | 0.0 | 0.2 | 0.0 |
| | | Neutral | 47.7 | 39.1 | 58.2 | 67.3 | 50.7 |
| | | Above Neutral | 52.3 | 60.9 | 41.8 | 32.5 | 49.3 |
| | Left | Mean | 32.5 | 24.4 | 27.1 | 26.3 | 29.0 |
| | | Median | 32.0 | 23.4 | 28.3 | 25.8 | 27.9 |
| | | Max | 73.7 | 67.0 | 59.3 | 62.8 | 73.7 |
| | | Min | -2.3 | 6.6 | -2.8 | 4.9 | -2.8 |
| | | ROM | 76.0 | 60.4 | 62.1 | 57.9 | 76.5 |
| | | ISV | 14.0 | 9.6 | 11.6 | 10.6 | 12.8 |
| | | Below Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Neutral | 18.6 | 37.2 | 32.6 | 27.9 | 26.1 |
| | | Above Neutral | 81.4 | 62.8 | 67.4 | 72.1 | 74.0 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| IR/ER | Right | Mean | 14.9 | -0.2 | 9.3 | 11.7 | 10.4 |
| | | Median | 14.2 | -0.8 | 9.2 | 11.0 | 10.4 |
| | | Max | 72.3 | 80.9 | 46.6 | 60.1 | 46.9 |
| | | Min | -27.1 | -36.4 | -15.0 | -13.2 | -36.4 |
| | | ROM | 99.4 | 117.3 | 61.6 | 73.2 | 83.3 |
| | | ISV | 10.0 | 9.8 | 8.4 | 8.7 | 11.1 |
| | | Below Neutral | 0.5 | 2.1 | 0.0 | 0.0 | 0.7 |
| | | Neutral | 71.4 | 95.0 | 89.5 | 82.9 | 80.8 |
| | | Above Neutral | 28.1 | 2.9 | 10.5 | 17.1 | 18.5 |
| | Left | Mean | 8.1 | -8.6 | -3.6 | 1.3 | 1.8 |
| | | Median | 7.3 | -9.9 | -4.7 | 1.9 | 0.2 |
| | | Max | 53.8 | 42.0 | 38.9 | 37.4 | 53.8 |
| | | Min | -37.7 | -46.9 | -36.8 | -59.6 | -59.6 |
| | | ROM | 91.4 | 88.9 | 75.7 | 96.9 | 113.3 |
| | | ISV | 19.2 | 14.5 | 14.0 | 14.6 | 18.1 |
| | | Below Neutral | 6.4 | 26.8 | 10.5 | 9.7 | 11.8 |
| | | Neutral | 63.6 | 71.3 | 83.4 | 81.9 | 71.1 |
| | | Above Neutral | 30.1 | 2.0 | 6.1 | 8.5 | 17.2 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

Table E.5.3: Conductor 5, Elbow.

| Rotation | Outcome Variable | | Sample # 02 | 07 | 08 | 09 | Overall |
|---|---|---|---|---|---|---|---|
| F/E | Right | Mean | 46.3 | 93.6 | 63.9 | 42.6 | 62.1 |
| | | Median | 44.2 | 94.3 | 64.2 | 41.2 | 60.2 |
| | | Max | 129.8 | 136.1 | 116.6 | 87.1 | 136.1 |
| | | Min | -4.2 | 5.9 | -5.0 | -1.9 | -5.0 |
| | | ROM | 133.9 | 130.2 | 121.6 | 89.0 | 141.1 |
| | | ISV | 16.9 | 15.6 | 13.0 | 15.2 | 23.7 |
| | | Below Neutral | 82.1 | 2.4 | 36.2 | 87.6 | 49.7 |
| | | Neutral | 17.1 | 63.6 | 63.1 | 12.4 | 42.8 |
| | | Above Neutral | 0.8 | 34.0 | 0.7 | 0.0 | 7.5 |
| | Left | Mean | 56.4 | 54.0 | 0.3 | 54.1 | 54.5 |
| | | Median | 57.9 | 57.9 | -2.4 | 57.5 | 57.6 |
| | | Max | 130.6 | 136.7 | 47.2 | 127.8 | 136.7 |
| | | Min | 0.8 | -4.1 | -38.0 | -1.6 | -4.2 |
| | | ROM | 129.8 | 140.7 | 85.2 | 129.4 | 140.9 |
| | | ISV | 20.8 | 28.2 | 16.4 | 22.8 | 23.7 |
| | | Below Neutral | 54.2 | 52.2 | 57.5 | 57.0 | 54.7 |
| | | Neutral | 44.6 | 43.3 | 40.2 | 41.9 | 43.3 |
| | | Above Neutral | 1.2 | 4.6 | 2.3 | 1.2 | 2.0 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

Table E.5.4: Conductor 5, Wrist.

| Rotation | Outcome Variable | | Sample # 02 | 07 | 08 | 09 | Overall |
|---|---|---|---|---|---|---|---|
| F/E | Right | Mean | 26.5 | 40.0 | -9.9 | 21.8 | 28.4 |
| | | Median | 26.0 | 41.0 | -9.7 | 22.1 | 26.4 |
| | | Max | 46.5 | 58.7 | 31.9 | 35.1 | 58.7 |
| | | Min | 6.0 | 0.7 | -22.3 | -5.3 | -10.0 |
| | | ROM | 40.5 | 58.1 | 54.2 | 40.5 | 68.8 |
| | | ISV | 6.4 | 8.0 | 4.3 | 3.7 | 8.7 |
| | | Below Neutral | 0.0 | 0.0 | 0.4 | 0.0 | 0.1 |
| | | Neutral | 0.0 | 0.3 | 0.6 | 0.5 | 0.2 |
| | | Above Neutral | 100.0 | 99.7 | 99.0 | 99.5 | 99.7 |
| | Left | Mean | 2.0 | -26.2 | -1.3 | -21.4 | -18.7 |
| | | Median | 2.8 | -27.0 | -0.3 | -22.0 | -20.5 |
| | | Max | 19.0 | 48.9 | 19.2 | 55.4 | 64.0 |
| | | Min | -24.8 | -57.6 | -29.4 | -57.2 | -57.6 |
| | | ROM | 43.8 | 106.5 | 48.5 | 112.6 | 121.7 |
| | | ISV | 6.9 | 13.8 | 8.6 | 12.5 | 14.9 |
| | | Below Neutral | 75.5 | 92.8 | 0.4 | 91.3 | 83.7 |
| | | Neutral | 12.5 | 4.1 | 0.6 | 5.7 | 8.8 |
| | | Above Neutral | 12.0 | 3.1 | 99.0 | 3.0 | 7.6 |
| RD/UD | Right | Mean | -8.4 | -0.3 | -9.9 | -8.7 | -7.0 |
| | | Median | -8.7 | -0.5 | -9.7 | -8.7 | -7.3 |
| | | Max | 42.5 | 36.2 | 31.9 | 26.5 | 19.5 |
| | | Min | -23.0 | -21.0 | -22.3 | -18.4 | -23.0 |
| | | ROM | 65.5 | 57.2 | 54.2 | 44.9 | 42.5 |
| | | ISV | 7.4 | 3.9 | 4.3 | 3.6 | 6.8 |
| | | Below Neutral | 68.5 | 7.5 | 93.4 | 86.4 | 62.5 |
| | | Neutral | 27.6 | 83.5 | 5.5 | 13.3 | 33.6 |
| | | Above Neutral | 4.0 | 9.0 | 1.1 | 0.3 | 4.0 |
| | Left | Mean | 2.0 | -3.7 | -1.3 | 0.1 | 0.0 |
| | | Median | 2.8 | -3.3 | -0.3 | 1.6 | 1.0 |
| | | Max | 19.0 | 15.7 | 19.2 | 17.1 | 19.2 |
| | | Min | -24.8 | -29.5 | -29.4 | -26.2 | -29.5 |
| | | ROM | 43.8 | 45.2 | 48.5 | 43.3 | 48.7 |
| | | ISV | 6.9 | 8.3 | 8.6 | 8.2 | 8.0 |
| | | Below Neutral | 18.6 | 41.4 | 32.1 | 27.3 | 26.8 |
| | | Neutral | 42.6 | 43.9 | 43.0 | 36.7 | 41.9 |
| | | Above Neutral | 38.8 | 14.7 | 24.8 | 36.0 | 31.3 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| P/S | Right | Mean | 67.6 | 131.5 | 85.9 | 7.0 | 86.9 |
| | | Median | 67.0 | 133.2 | 86.0 | 5.9 | 81.6 |
| | | Max | 113.3 | 158.3 | 134.5 | 51.3 | 158.3 |
| | | Min | 12.5 | 16.8 | 7.7 | -16.1 | 25.5 |
| | | ROM | 100.8 | 141.5 | 126.8 | 67.4 | 132.8 |
| | | ISV | 12.5 | 16.9 | 7.8 | 8.5 | 27.3 |
| | | Below Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Above Neutral | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| | Left | Mean | 64.1 | 101.2 | 90.6 | 77.2 | 77.8 |
| | | Median | 59.4 | 101.0 | 84.4 | 68.5 | 69.9 |
| | | Max | 179.2 | 186.7 | 174.3 | 186.2 | 186.7 |
| | | Min | 4.4 | 1.5 | 11.4 | -8.8 | -8.8 |
| | | ROM | 174.8 | 185.2 | 162.8 | 195.0 | 195.0 |
| | | ISV | 31.7 | 31.3 | 34.9 | 36.6 | 36.3 |
| | | Below Neutral | 0.0 | 0 | 0.0 | 0.0 | 0.0 |
| | | Neutral | 4.0 | 1.8 | 1.0 | 3.2 | 3.0 |
| | | Above Neutral | 96.0 | 98.2 | 99.0 | 96.8 | 97.0 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

Table E.5.5: Conductor 5, Trunk.

| Rotation | Outcome Variable | Sample # 02 | 07 | 08 | 09 | Overall |
|---|---|---|---|---|---|---|
| F/E | Mean | 10.9 | 9.6 | 8.3 | 8.1 | 9.8 |
| | Median | 8.9 | 7.8 | 6.1 | 6.0 | 7.7 |
| | Max | 40.7 | 38.1 | 38.6 | 45.1 | 45.1 |
| | Min | -7.5 | -7.8 | -9.5 | -5.4 | -9.5 |
| | ROM | 48.2 | 45.8 | 48.1 | 50.5 | 54.6 |
| | ISV | 10.0 | 8.8 | 8.8 | 8.3 | 9.4 |
| | Below Neutral | 0.5 | 1.4 | 0.3 | 0.2 | 0.6 |
| | Neutral | 33.7 | 31.2 | 41.6 | 42.4 | 35.8 |
| | Above Neutral | 65.8 | 67.4 | 58.1 | 57.4 | 63.6 |
| RLB/LLB | Mean | 5.0 | -1.1 | 1.8 | 2.4 | 2.8 |
| | Median | 5.3 | -0.6 | 2.6 | 3.0 | 3.0 |
| | Max | 23.2 | 13.7 | 14.6 | 14.4 | 23.2 |
| | Min | 10.6 | -19.8 | -15.5 | -13.9 | -19.8 |
| | ROM | 33.9 | 33.5 | 30.1 | 28.3 | 43.0 |
| | ISV | 5.9 | 5.9 | 6.1 | 5.4 | 6.3 |
| | Below Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Neutral | 99.7 | 100.0 | 100.0 | 100.0 | 99.9 |
| | Above Neutral | 0.3 | 0.0 | 0.0 | 0.0 | 0.1 |
| RAR/LAR | Mean | 3.7 | 1.1 | 1.1 | 1.5 | 2.4 |
| | Median | 3.9 | 1.4 | 1.1 | 0.8 | 2.2 |
| | Max | 26.7 | 18.2 | 10.9 | 15.2 | 26.7 |
| | Min | -17.0 | -20.3 | -8.9 | -9.8 | -20.3 |
| | ROM | 43.7 | 38.5 | 19.8 | 25.0 | 47.0 |
| | ISV | 5.8 | 4.6 | 3.7 | 3.8 | 5.2 |
| | Below Neutral | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 |
| | Neutral | 98.8 | 99.9 | 100.0 | 100.0 | 99.4 |
| | Above Neutral | 1.2 | 0.0 | 0.0 | 0.0 | 0.6 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

**Appendix E.6: Neck**

Table E.6.1: Conductor 6, Neck.

| Rotation | Outcome Variable | Sample # 1 | 2 | 4 | 6 | 7 | 9 | 12 | 13 | 15 | 17 | 18 | 19 | Overall |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F/E | Mean | 25.1 | 24.1 | 24.2 | 26.2 | 27.8 | 27.0 | 26.8 | 28.5 | 30.8 | 27.0 | 26.5 | 27.1 | 26.5 |
| | Median | 25.6 | 25.3 | 24.6 | 27.1 | 28.9 | 27.9 | 28.0 | 28.5 | 31.3 | 27.7 | 27.9 | 27.8 | 27.3 |
| | Max | 57.2 | 47.9 | 52.0 | 52.4 | 57.4 | 53.0 | 47.5 | 51.0 | 50.0 | 53.5 | 49.2 | 55.3 | 57.4 |
| | Min | -5.2 | -6.2 | -9.0 | -3.7 | -6.7 | -9.6 | -3.9 | 2.0 | 1.2 | -3.9 | -3.9 | -4.4 | -9.6 |
| | ROM | 62.4 | 54.0 | 61.1 | 56.2 | 64.1 | 62.6 | 51.3 | 49.0 | 48.8 | 57.5 | 53.1 | 59.7 | 66.9 |
| | ISV | 8.4 | 9.6 | 8.4 | 9.0 | 7.8 | 8.1 | 7.4 | 6.8 | 7.0 | 9.0 | 10.0 | 8.3 | 8.5 |
| | Below Neutral | 0.9 | 2.6 | 1.9 | 0.5 | 1.5 | 0.7 | 1.2 | 0.0 | 0.0 | 1.5 | 2.2 | 1.0 | 1.2 |
| | Neutral | 4.9 | 7.7 | 2.9 | 7.2 | 1.8 | 4.1 | 2.8 | 1.9 | 1.2 | 4.1 | 6.9 | 3.4 | 4.1 |
| | Above Neutral | 94.2 | 89.7 | 95.2 | 92.4 | 96.7 | 95.2 | 95.9 | 98.1 | 98.8 | 94.5 | 90.9 | 95.6 | 94.8 |
| RLB/LLB | Mean | 0.0 | 1.7 | -0.6 | 1.8 | 1.3 | -0.5 | 0.8 | 2.5 | 1.6 | 0.2 | 3.7 | 3.3 | 1.0 |
| | Median | -0.2 | 1.8 | -0.9 | 2.2 | 1.5 | -0.2 | 1.6 | 3.1 | 1.6 | 0.9 | 3.9 | 4.1 | 1.3 |
| | Max | 19.4 | 17.3 | 21.0 | 17.6 | 20.4 | 16.5 | 14.8 | 15.3 | 14.1 | 13.5 | 17.6 | 18.0 | 21.0 |
| | Min | -19.8 | -18.0 | -17.4 | -22.4 | -13.5 | -20.8 | -15.2 | -17.0 | -16.7 | -19.9 | -10.7 | -12.2 | -22.4 |
| | ROM | 39.2 | 35.3 | 38.4 | 40.0 | 33.9 | 37.3 | 29.9 | 32.3 | 30.8 | 33.4 | 28.3 | 30.2 | 43.4 |
| | ISV | 6.9 | 5.9 | 6.3 | 5.6 | 6.2 | 6.5 | 5.2 | 5.9 | 5.7 | 6.0 | 6.3 | 5.4 | 6.2 |
| | Below Neutral | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Neutral | 100.0 | 100.0 | 99.9 | 99.9 | 99.9 | 99.9 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| | Above Neutral | 0.0 | 0.0 | 0.1 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| RAR/LAR | Mean | -0.7 | -1.2 | -2.4 | -1.8 | -0.1 | -2.3 | 2.0 | -3.6 | -0.2 | -0.9 | -2.7 | 0.0 | -1.2 |
| | Median | -0.8 | -1.3 | -2.2 | -3.1 | -0.3 | -2.2 | 1.4 | -4.0 | -1.2 | -0.6 | -2.1 | -1.6 | -1.6 |
| | Max | 51.1 | 41.6 | 30.3 | 42.0 | 34.4 | 37.6 | 18.4 | 41.5 | 26.3 | 39.5 | 39.8 | 22.4 | 51.1 |
| | Min | -48.0 | -44.8 | -46.6 | -33.5 | -40.2 | -41.5 | -34.8 | -36.4 | -20.7 | -33.0 | -36.4 | -23.7 | -48.0 |
| | ROM | 99.1 | 86.4 | 76.9 | 75.4 | 74.6 | 79.1 | 53.2 | 78.0 | 47.0 | 72.5 | 76.2 | 46.1 | 99.1 |
| | ISV | 9.2 | 10.3 | 7.3 | 9.6 | 8.5 | 8.2 | 7.0 | 7.8 | 8.7 | 7.0 | 8.3 | 8.4 | 8.6 |
| | Below Neutral | 2.2 | 3.0 | 1.3 | 0.7 | 0.9 | 2.2 | 0.5 | 1.4 | 0.1 | 1.0 | 3.0 | 0.2 | 1.4 |
| | Neutral | 96.7 | 95.2 | 98.5 | 96.0 | 96.9 | 97.2 | 99.5 | 98.2 | 98.7 | 98.6 | 96.2 | 99.4 | 97.6 |
| | Above Neutral | 1.2 | 1.9 | 0.2 | 3.4 | 2.2 | 0.6 | 0.0 | 0.5 | 1.2 | 0.4 | 0.8 | 0.4 | 1.1 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

Table E.6.2: Conductor 6, Shoulder.

| Rotation | Outcome Variable | | Sample # 1 | 2 | 4 | 6 | 7 | 9 | 12 | 13 | 15 | 17 | 18 | 19 | Overall |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F/E | Right | Mean | 40.1 | 37.9 | 33.3 | 28.8 | 36.3 | 32.1 | 32.8 | 39.8 | 31.5 | 27.9 | 30.8 | 32.5 | 33.9 |
| | | Median | 39.5 | 37.3 | 32.3 | 28.1 | 35.5 | 31.3 | 32.1 | 39.4 | 31.1 | 26.6 | 28.4 | 31.8 | 33.2 |
| | | Max | 80.7 | 76.4 | 86.4 | 67.3 | 68.3 | 95.0 | 61.0 | 71.4 | 77.8 | 61.1 | 87.7 | 72.9 | 95.0 |
| | | Min | 6.6 | 5.2 | -5.3 | 3.4 | 9.4 | 7.0 | 19.5 | 12.6 | 7.5 | -0.2 | 10.4 | 10.2 | -5.3 |
| | | ROM | 74.1 | 71.2 | 91.6 | 63.9 | 58.9 | 88.0 | 41.6 | 58.8 | 70.3 | 61.3 | 77.3 | 62.7 | 100.3 |
| | | ISV | 9.0 | 8.2 | 11.1 | 9.1 | 9.1 | 9.2 | 5.7 | 7.8 | 8.6 | 9.3 | 12.3 | 8.6 | 9.9 |
| | | Below Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Neutral | 0.8 | 1.0 | 10.0 | 14.7 | 2.3 | 6.9 | 0.0 | 1.0 | 7.1 | 18.3 | 16.4 | 5.5 | 6.5 |
| | | Above Neutral | 99.2 | 99.0 | 90.0 | 85.3 | 97.7 | 93.1 | 100.0 | 99.0 | 92.9 | 81.7 | 83.6 | 94.5 | 93.5 |
| | Left | Mean | 26.0 | 22.7 | 18.4 | 16.9 | 16.0 | 16.5 | 13.7 | 13.0 | 8.5 | 10.0 | 13.3 | 14.8 | 16.8 |
| | | Median | 25.4 | 18.7 | 16.4 | 10.9 | 8.4 | 13.3 | 10.0 | 5.6 | 4.4 | 2.8 | 6.7 | 6.9 | 12.0 |
| | | Max | 79.7 | 95.0 | 87.8 | 86.7 | 102.7 | 78.9 | 75.9 | 80.5 | 118.7 | 84.1 | 92.0 | 86.8 | 118.7 |
| | | Min | -40.4 | -13.3 | -28.2 | -9.6 | -16.8 | -12.4 | -19.4 | -13.3 | -17.9 | -8.2 | -20.4 | -14.5 | -40.4 |
| | | ROM | 120.0 | 108.3 | 116.1 | 96.3 | 119.6 | 91.3 | 95.3 | 93.8 | 136.5 | 92.3 | 112.4 | 101.3 | 159.0 |
| | | ISV | 18.4 | 18.6 | 18.2 | 15.6 | 18.0 | 17.4 | 16.7 | 17.2 | 16.6 | 16.4 | 23.4 | 17.7 | 18.3 |
| | | Below Neutral | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 |
| | | Neutral | 38.2 | 51.7 | 55.6 | 62.8 | 62.6 | 63.2 | 61.5 | 63.0 | 78.7 | 77.6 | 71.3 | 69.2 | 60.9 |
| | | Above Neutral | 61.8 | 48.2 | 44.4 | 37.2 | 37.4 | 36.8 | 38.5 | 37.0 | 21.3 | 22.4 | 28.6 | 30.8 | 39.1 |
| ABD/ ADD | Right | Mean | 34.4 | 30.0 | 35.1 | 30.5 | 30.8 | 30.4 | 27.1 | 30.9 | 30.9 | 31.0 | 30.9 | 32.2 | 31.6 |
| | | Median | 33.8 | 29.2 | 34.0 | 30.4 | 30.2 | 29.7 | 27.1 | 30.6 | 30.6 | 30.0 | 30.1 | 31.8 | 30.8 |
| | | Max | 70.1 | 61.4 | 82.2 | 68.2 | 65.3 | 81.3 | 47.5 | 71.5 | 64.4 | 74.3 | 68.2 | 75.0 | 82.2 |
| | | Min | 10.5 | 11.2 | 20.3 | 13.2 | 14.9 | 2.5 | 4.7 | 9.0 | 11.6 | 11.4 | 8.1 | 11.1 | 2.5 |
| | | ROM | 59.6 | 50.2 | 62.0 | 55.1 | 50.3 | 78.8 | 42.9 | 62.5 | 52.9 | 62.9 | 60.1 | 63.9 | 79.7 |
| | | ISV | 7.3 | 6.8 | 6.7 | 5.3 | 5.6 | 6.4 | 4.1 | 5.9 | 5.5 | 6.7 | 7.9 | 5.3 | 6.6 |
| | | Below Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Neutral | 1.4 | 3.6 | 0.0 | 2.3 | 0.6 | 2.6 | 3.1 | 2.4 | 1.3 | 0.6 | 5.5 | 0.5 | 1.7 |
| | | Above Neutral | 98.6 | 96.4 | 100.0 | 97.7 | 99.4 | 97.5 | 96.7 | 97.6 | 98.7 | 99.4 | 94.5 | 99.5 | 98.3 |
| | Left | Mean | 25.4 | 24.1 | 23.4 | 19.4 | 21.6 | 22.1 | 18.9 | 22.5 | 20.0 | 21.7 | 24.1 | 20.7 | 22.1 |
| | | Median | 24.4 | 22.8 | 22.4 | 20.3 | 20.7 | 21.0 | 19.3 | 21.6 | 18.5 | 21.0 | 21.1 | 20.5 | 21.3 |
| | | Max | 88.4 | 66.1 | 76.9 | 55.5 | 62.1 | 81.4 | 48.5 | 59.3 | 73.5 | 69.5 | 76.2 | 65.4 | 88.4 |
| | | Min | 3.8 | 4.3 | 3.5 | 0.6 | 3.3 | -6.3 | -4.2 | 0.8 | 6.3 | 4.6 | 9.7 | -0.6 | -6.3 |
| | | ROM | 84.5 | 61.9 | 73.4 | 54.9 | 58.8 | 87.7 | 52.8 | 58.6 | 67.2 | 64.9 | 66.5 | 65.9 | 94.6 |
| | | ISV | 9.2 | 9.6 | 8.7 | 6.4 | 8.0 | 9.6 | 6.6 | 7.8 | 8.3 | 8.0 | 9.4 | 7.7 | 8.7 |
| | | Below Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Neutral | 20.1 | 24.0 | 25.4 | 46.9 | 37.6 | 39.3 | 60.5 | 35.7 | 62.3 | 35.3 | 40.7 | 44.9 | 37.2 |
| | | Above Neutral | 80.0 | 76.0 | 74.6 | 53.1 | 62.4 | 60.7 | 39.5 | 64.3 | 37.7 | 64.7 | 59.3 | 55.1 | 62.8 |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IR/ER | Right | Mean | 10.5 | 7.8 | 3.8 | 1.5 | 10.1 | 6.3 | -2.4 | 2.4 | -4.2 | 0.5 | 6.8 | 4.1 | 4.5 |
| | | Median | 9.8 | 6.8 | 3.1 | 0.8 | 9.7 | 4.9 | -2.8 | 1.7 | -5.6 | -0.1 | 4.9 | 3.4 | 3.6 |
| | | Max | 59.9 | 61.4 | 69.8 | 51.4 | 49.7 | 74.4 | 32.0 | 48.7 | 55.6 | 42.3 | 58.1 | 46.2 | 74.4 |
| | | Min | -27.1 | -21.5 | -29.3 | -25.6 | -20.4 | -37.0 | -16.4 | -28.2 | -27.5 | -48.5 | -15.5 | -21.2 | -48.5 |
| | | ROM | 86.9 | 82.9 | 99.2 | 77.0 | 70.1 | 111.4 | 48.4 | 76.9 | 83.1 | 90.9 | 73.6 | 67.5 | 123.0 |
| | | ISV | 9.8 | 9.3 | 12.5 | 10.1 | 9.0 | 11.3 | 5.9 | 7.9 | 11.5 | 9.5 | 10.8 | 8.8 | 10.9 |
| | | Below Neutral | 0.1 | 0.0 | 1.4 | 0.7 | 0.1 | 0.1 | 0.0 | 0.4 | 4.7 | 1.3 | 0.0 | 0.0 | 0.7 |
| | | Neutral | 85.1 | 91.4 | 90.5 | 95.6 | 87.8 | 87.7 | 99.4 | 97.0 | 91.7 | 95.5 | 89.1 | 95.0 | 91.5 |
| | | Above Neutral | 14.8 | 8.5 | 8.1 | 3.7 | 12.1 | 12.3 | 0.7 | 2.6 | 3.6 | 3.2 | 10.9 | 5.0 | 7.8 |
| | Left | Mean | -6.0 | -5.2 | -8.8 | -8.3 | -9.6 | -8.9 | -11.2 | -14.2 | -16.2 | -10.7 | -13.5 | -5.4 | -9.0 |
| | | Median | -6.7 | -11.4 | -15.4 | -13.8 | -15.1 | -16.2 | -13.7 | -21.7 | -24.7 | -17.9 | -16.4 | -13.6 | -14.7 |
| | | Max | 47.6 | 60.4 | 55.4 | 54.2 | 71.3 | 52.0 | 41.4 | 50.5 | 79.2 | 53.9 | 61.0 | 55.9 | 79.2 |
| | | Min | -82.1 | -45.6 | -55.9 | -47.7 | -64.1 | -62.2 | -48.9 | -56.0 | -61.5 | -39.1 | -61.9 | -50.2 | -82.1 |
| | | ROM | 129.6 | 106.0 | 111.3 | 101.9 | 135.5 | 114.2 | 90.2 | 106.5 | 140.8 | 93.0 | 122.9 | 106.1 | 161.3 |
| | | ISV | 18.4 | 18.2 | 18.1 | 18.2 | 19.0 | 21.2 | 20.3 | 18.6 | 24.2 | 18.4 | 23.3 | 20.2 | 19.8 |
| | | Below Neutral | 27.9 | 21.4 | 35.5 | 32.7 | 31.6 | 41.8 | 41.1 | 53.8 | 55.0 | 36.6 | 41.2 | 29.9 | 35.9 |
| | | Neutral | 62.0 | 67.7 | 58.1 | 55.8 | 59.8 | 44.7 | 51.4 | 39.4 | 36.7 | 54.1 | 50.2 | 53.1 | 53.9 |
| | | Above Neutral | 10.1 | 10.9 | 6.4 | 11.6 | 8.6 | 13.5 | 7.6 | 6.8 | 8.3 | 9.3 | 8.6 | 17.0 | 10.2 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

Table E.6.3: Conductor 6, Elbow.

| Rotation | Outcome Variable | | Sample # 1 | 2 | 4 | 6 | 7 | 9 | 12 | 13 | 15 | 17 | 18 | 19 | Overall |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F/E | Right | Mean | 77.7 | 74.6 | 85.5 | 80.8 | 78.2 | 80.0 | 70.7 | 75.7 | 86.3 | 82.4 | 83.4 | 80.4 | 79.7 |
| | | Median | 76.6 | 74.5 | 84.4 | 80.1 | 78.1 | 80.0 | 71.1 | 74.3 | 84.3 | 82.4 | 84.8 | 80.4 | 78.6 |
| | | Max | 126.0 | 141.4 | 145.0 | 133.0 | 108.4 | 121.8 | 99.9 | 132.2 | 144.1 | 115.7 | 116.3 | 120.5 | 145.0 |
| | | Min | 31.3 | 22.6 | 22.9 | 46.4 | 39.6 | 35.2 | 23.5 | 35.2 | 40.9 | 35.5 | 28.7 | 30.2 | 22.6 |
| | | ROM | 94.7 | 118.8 | 122.1 | 86.7 | 68.8 | 86.7 | 76.4 | 97.0 | 103.2 | 80.2 | 87.6 | 90.3 | 122.4 |
| | | ISV | 14.7 | 10.4 | 17.9 | 11.2 | 11.3 | 12.8 | 5.6 | 13.9 | 16.2 | 12.1 | 14.8 | 11.0 | 13.8 |
| | | Below Neutral | 10.7 | 7.1 | 5.8 | 1.9 | 5.3 | 6.2 | 2.0 | 8.9 | 2.3 | 3.4 | 7.7 | 2.9 | 5.5 |
| | | Neutral | 81.6 | 92.6 | 74.1 | 93.2 | 92.9 | 88.9 | 98.0 | 85.6 | 79.0 | 89.7 | 80.5 | 94.3 | 87.3 |
| | | Above Neutral | 7.7 | 0.3 | 20.1 | 4.9 | 1.8 | 4.9 | 0.0 | 5.6 | 18.7 | 6.9 | 11.7 | 2.8 | 7.2 |
| | Left | Mean | 54.8 | 59.1 | 56.8 | 54.3 | 61.8 | 57.7 | 63.4 | 66.8 | 53.0 | 60.3 | 51.4 | 60.8 | 58.3 |
| | | Median | 51.9 | 57.9 | 53.4 | 52.9 | 61.3 | 56.1 | 57.5 | 61.5 | 48.8 | 55.4 | 51.4 | 59.7 | 55.6 |
| | | Max | 149.0 | 146.4 | 153.0 | 146.9 | 142.4 | 147.6 | 152.9 | 151.7 | 150.2 | 136.2 | 144.5 | 142.7 | 153.0 |
| | | Min | 13.9 | 0.7 | 8.4 | -1.9 | 2.7 | -1.5 | 23.1 | 29.9 | 5.5 | 21.1 | -2.9 | 5.0 | -2.9 |
| | | ROM | 135.0 | 145.6 | 144.7 | 148.7 | 139.7 | 149.2 | 129.8 | 121.8 | 144.7 | 115.1 | 147.4 | 137.7 | 155.9 |
| | | ISV | 19.6 | 18.9 | 21.3 | 23.5 | 21.1 | 20.8 | 24.4 | 24.4 | 21.3 | 17.6 | 24.4 | 19.5 | 21.5 |
| | | Below Neutral | 68.4 | 55.8 | 68.4 | 72.5 | 46.6 | 61.6 | 58.6 | 47.2 | 77.3 | 64.1 | 74.5 | 50.3 | 61.9 |
| | | Neutral | 28.6 | 40.9 | 27.1 | 22.8 | 49.4 | 34.5 | 33.2 | 42.9 | 18.9 | 31.8 | 21.9 | 45.0 | 33.5 |
| | | Above Neutral | 3.0 | 3.3 | 4.5 | 4.7 | 4.0 | 3.9 | 8.2 | 9.9 | 3.8 | 4.1 | 3.6 | 4.8 | 4.6 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

Table E.6.4: Conductor 6, Wrist.

| Rotation | Outcome Variable | | Sample # | | | | | | | | | | | | Overall |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 4 | 6 | 7 | 9 | 12 | 13 | 15 | 17 | 18 | 19 | |
| F/E | Right | Mean | -10.2 | -6.5 | -10.1 | -6.0 | -9.3 | -6.5 | -19.3 | -14.5 | -12.8 | -5.2 | -6.0 | -9.7 | -9.4 |
| | | Median | -10.5 | -6.6 | -10.3 | -6.2 | -9.5 | -6.9 | -19.7 | -14.1 | -13.0 | -5.4 | -6.4 | -9.8 | -8.8 |
| | | Max | 13.9 | 7.7 | 19.6 | 13.2 | 4.4 | 12.9 | 2.4 | 7.9 | 3.6 | 12.9 | 8.9 | 3.4 | 19.6 |
| | | Min | -21.3 | -17.5 | -20.4 | -13.1 | -19.1 | -15.7 | -25.3 | -29.5 | -21.7 | -13.8 | -15.4 | -21.1 | -29.5 |
| | | ROM | 35.2 | 25.3 | 40.0 | 26.3 | 23.5 | 28.6 | 27.7 | 37.4 | 25.3 | 26.7 | 24.4 | 24.5 | 49.1 |
| | | ISV | 3.3 | 2.9 | 3.0 | 2.5 | 2.9 | 3.0 | 2.6 | 5.5 | 2.8 | 2.7 | 3.2 | 3.0 | 4.8 |
| | | Below Neutral | 94.1 | 73.0 | 95.4 | 69.0 | 92.8 | 74.1 | 99.6 | 96.2 | 99.2 | 56.5 | 68.6 | 94.2 | 85.0 |
| | | Neutral | 5.7 | 26.2 | 4.5 | 30.8 | 7.2 | 25.4 | 0.4 | 3.7 | 0.8 | 43.4 | 30.4 | 5.8 | 14.8 |
| | | Above Neutral | 0.2 | 0.8 | 0.1 | 0.2 | 0.0 | 0.5 | 0.0 | 0.0 | 0.0 | 0.2 | 1.1 | 0.0 | 0.2 |
| | Left | Mean | -7.2 | -6.4 | -12.4 | -11.2 | -8.9 | -7.1 | -15.7 | -12.1 | -9.5 | -7.4 | -6.8 | -9.8 | -9.5 |
| | | Median | -7.3 | -5.9 | -12.2 | -12.0 | -8.7 | -7.3 | -16.1 | -11.5 | -9.7 | -8.2 | -6.5 | -9.3 | -9.4 |
| | | Max | 25.5 | 24.9 | 17.3 | 12.7 | 17.3 | 25.3 | 14.6 | 12.4 | 13.7 | 13.4 | 12.9 | 16.8 | 25.5 |
| | | Min | -19.4 | -29.6 | -32.7 | -25.4 | -24.6 | -23.2 | -34.4 | -30.3 | -26.3 | -20.2 | -18.7 | -28.1 | -34.4 |
| | | ROM | 44.9 | 54.5 | 50.0 | 38.1 | 41.9 | 48.5 | 49.0 | 42.8 | 40.1 | 33.6 | 31.6 | 44.8 | 59.9 |
| | | ISV | 5.6 | 5.8 | 7.4 | 6.5 | 5.9 | 6.4 | 9.1 | 7.0 | 6.0 | 4.8 | 5.5 | 6.3 | 7.0 |
| | | Below Neutral | 73.6 | 57.7 | 87.4 | 82.4 | 73.5 | 63.9 | 85.4 | 89.4 | 81.1 | 77.4 | 58.6 | 78.8 | 75.8 |
| | | Neutral | 22.8 | 39.4 | 10.1 | 15.4 | 24.9 | 32.6 | 10.4 | 7.3 | 16.5 | 18.9 | 37.4 | 19.0 | 21.3 |
| | | Above Neutral | 3.4 | 3.0 | 1.8 | 2.2 | 1.6 | 3.5 | 4.2 | 3.3 | 2.4 | 3.7 | 4.0 | 2.2 | 2.8 |
| RD/UD | Right | Mean | -0.4 | -5.2 | -0.7 | -4.4 | 0.4 | -3.5 | 5.2 | 1.8 | 1.8 | -6.6 | -4.9 | -1.2 | -1.6 |
| | | Median | -0.8 | -5.7 | -0.7 | -4.5 | 0.4 | -3.8 | 5.2 | 2.1 | 2.0 | -6.7 | -5.4 | -1.2 | -1.8 |
| | | Max | 15.1 | 16.4 | 17.5 | 11.5 | 13.9 | 15.2 | 17.7 | 20.1 | 18.3 | 8.6 | 10.0 | 17.5 | 20.1 |
| | | Min | -24.6 | -17.6 | -24.1 | -17.8 | -16.5 | -18.8 | -6.3 | -19.5 | -17.1 | -18.0 | -17.0 | -12.9 | -24.6 |
| | | ROM | 39.8 | 34.0 | 41.6 | 29.3 | 30.5 | 33.9 | 24.0 | 39.6 | 35.4 | 26.6 | 26.9 | 30.4 | 44.7 |
| | | ISV | 4.3 | 3.8 | 4.4 | 3.4 | 3.8 | 3.9 | 2.1 | 4.2 | 2.8 | 3.7 | 3.9 | 3.8 | 4.9 |
| | | Below Neutral | 12.2 | 58.7 | 15.9 | 43.1 | 7.9 | 36.6 | 0.0 | 6.1 | 1.1 | 67.6 | 54.3 | 16.9 | 26.1 |
| | | Neutral | 76.1 | 39.6 | 74.7 | 55.9 | 81.8 | 6.1 | 46.6 | 7.4 | 87.3 | 32.0 | 43.7 | 78.9 | 64.4 |
| | | Above Neutral | 11.7 | 1.7 | 9.4 | 1.0 | 10.4 | 2.4 | 53.4 | 19.9 | 11.7 | 0.4 | 2.0 | 4.3 | 9.6 |
| | Left | Mean | -2.2 | 0.7 | 0.2 | 2.9 | -0.2 | 0.1 | 6.9 | 3.1 | 5.0 | -1.5 | -0.8 | 0.6 | 0.9 |
| | | Median | -1.1 | -0.7 | -0.7 | 1.9 | -1.1 | -0.9 | 5.7 | 3.6 | 7.7 | -2.6 | -0.5 | -2.8 | -0.2 |
| | | Max | 29.9 | 36.9 | 38.1 | 34.2 | 33.6 | 34.6 | 36.5 | 37.2 | 34.7 | 28.4 | 27.9 | 34.6 | 38.1 |
| | | Min | -54.3 | -48.5 | -47.2 | -44.2 | -49.6 | -50.7 | -41.8 | -48.6 | -31.5 | -39.7 | -41.2 | -38.3 | -54.3 |
| | | ROM | 84.2 | 85.4 | 85.3 | 78.4 | 83.2 | 85.3 | 78.3 | 85.8 | 66.2 | 68.1 | 69.1 | 73.0 | 92.4 |
| | | ISV | 11.7 | 12.2 | 12.3 | 11.8 | 13.6 | 12.5 | 11.4 | 12.3 | 14.2 | 10.4 | 12.3 | 13.9 | 12.6 |
| | | Below Neutral | 40.4 | 32.2 | 33.1 | 24.6 | 40.5 | 37.4 | 13.7 | 30.9 | 30.3 | 36.1 | 39.7 | 39.6 | 33.7 |
| | | Neutral | 31.0 | 37.3 | 30.9 | 37.4 | 26.6 | 29.3 | 33.8 | 22.3 | 15.7 | 42.2 | 22.2 | 27.0 | 30.4 |
| | | Above Neutral | 28.6 | 30.4 | 36.0 | 38.0 | 32.9 | 33.3 | 52.5 | 46.8 | 54.0 | 21.8 | 38.1 | 33.4 | 35.8 |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P/S | Right | Mean | 31.3 | 29.5 | 18.3 | 24.9 | 23.1 | 19.6 | 61.3 | 45.7 | 35.3 | 13.7 | 14.3 | 21.4 | 27.0 |
| | | Median | 31.4 | 28.2 | 18.6 | 24.9 | 20.1 | 18.7 | 61.7 | 49.4 | 37.0 | 14.2 | 12.0 | 16.2 | 24.0 |
| | | Max | 95.2 | 113.3 | 91.8 | 110.1 | 117.3 | 119.8 | 106.4 | 109.4 | 122.5 | 56.9 | 106.2 | 118.9 | 122.5 |
| | | Min | -17.1 | -17.4 | -28.5 | -20.6 | -13.9 | -18.6 | 25.5 | -19.3 | -24.6 | -21.1 | -18.5 | -19.7 | -28.5 |
| | | ROM | 112.3 | 130.8 | 120.3 | 130.7 | 131.2 | 138.5 | 80.9 | 128.7 | 147.1 | 77.9 | 124.7 | 138.6 | 150.9 |
| | | ISV | 16.1 | 13.9 | 15.9 | 13.0 | 17.6 | 15.9 | 7.2 | 18.1 | 18.0 | 11.9 | 17.9 | 20.9 | 19.8 |
| | | Below Neutral | 0.0 | 0.0 | 0.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.0 | 0.0 | 0.1 |
| | | Neutral | 24.9 | 25.0 | 62.9 | 34.9 | 49.8 | 54.1 | 0.0 | 10.0 | 18.4 | 69.6 | 73.1 | 56.5 | 41.4 |
| | | Above Neutral | 75.1 | 72.0 | 36.6 | 65.1 | 50.2 | 45.9 | 100.0 | 90.0 | 81.5 | 30.3 | 26.9 | 43.5 | 58.5 |
| | Left | Mean | 65.4 | 55.5 | 68.1 | 71.6 | 58.5 | 65.9 | 59.7 | 62.8 | 77.0 | 51.6 | 56.6 | 59.8 | 63.4 |
| | | Median | 72.2 | 60.6 | 76.0 | 77.4 | 59.6 | 72.2 | 70.4 | 71.4 | 85.8 | 50.1 | 56.5 | 64.6 | 69.6 |
| | | Max | 125.2 | 116.9 | 120.8 | 135.2 | 129.7 | 123.1 | 116.9 | 116.7 | 132.4 | 107.3 | 123.0 | 115.5 | 135.2 |
| | | Min | -89.0 | -72.3 | -78.8 | -83.7 | -68.3 | -76.5 | -77.2 | -79.6 | -74.1 | -60.7 | -76.5 | -72.9 | -89.0 |
| | | ROM | 214.2 | 189.2 | 199.6 | 219.0 | 198.0 | 199.6 | 194.2 | 196.3 | 206.4 | 168.0 | 199.5 | 188.4 | 224.2 |
| | | ISV | 33.0 | 33.0 | 32.3 | 32.0 | 30.2 | 32.2 | 39.7 | 34.6 | 33.6 | 26.7 | 41.9 | 30.3 | 33.4 |
| | | Below Neutral | 4.0 | 4.0 | 3.0 | 3.4 | 2.9 | 3.9 | 8.4 | 5.0 | 3.2 | 3.4 | 7.9 | 3.3 | 4.0 |
| | | Neutral | 4.1 | 9.3 | 5.3 | 1.6 | 6.5 | 3.7 | 3.6 | 2.7 | 2.5 | 3.2 | 8.3 | 4.6 | 4.6 |
| | | Above Neutral | 92.0 | 86.7 | 91.7 | 96.0 | 90.6 | 92.3 | 89.7 | 92.3 | 94.3 | 93.3 | 83.8 | 92.1 | 91.4 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

Table E.6.5: Conductor 6, Trunk.

| Rotation | Outcome Variable | Sample # 1 | 2 | 4 | 6 | 7 | 9 | 12 | 13 | 15 | 17 | 18 | 19 | Overall |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F/E | Mean | -0.1 | 1.0 | 1.7 | 3.6 | -1.5 | 0.3 | -1.9 | -0.4 | 0.6 | 1.0 | -1.5 | 1.3 | 0.6 |
| | Median | -0.3 | 0.8 | 1.7 | 2.9 | -1.5 | 0.5 | -1.8 | -0.4 | 0.6 | 0.9 | -1.4 | 1.1 | 0.5 |
| | Max | 21.2 | 23.0 | 27.0 | 28.4 | 17.5 | 11.5 | 16.6 | 13.3 | 5.1 | 20.1 | 6.9 | 19.4 | 28.4 |
| | Min | -19.5 | -15.3 | -16.1 | -10.8 | -21.9 | -17.6 | -11.6 | -12.9 | -2.5 | -11.4 | -13.1 | -12.4 | -21.9 |
| | ROM | 40.7 | 38.3 | 43.0 | 39.2 | 39.5 | 29.1 | 28.3 | 26.1 | 7.6 | 31.5 | 20.0 | 31.8 | 50.4 |
| | ISV | 5.3 | 4.3 | 4.5 | 4.6 | 5.3 | 4.3 | 3.3 | 3.3 | 1.2 | 3.3 | 3.2 | 3.1 | 4.4 |
| | Below Neutral | 17.5 | 5.8 | 6.0 | 10.0 | 26.0 | 8.6 | 20.0 | 9.5 | 0.0 | 3.1 | 12.9 | 2.0 | 9.2 |
| | Neutral | 67.8 | 8.6 | 75.0 | 68.6 | 63.5 | 78.5 | 77.9 | 85.5 | 99.9 | 88.5 | 86.3 | 90.9 | 78.6 |
| | Above Neutral | 14.7 | 13.6 | 19.0 | 30.4 | 10.5 | 13.0 | 2.1 | 5.0 | 0.1 | 8.4 | 0.8 | 7.1 | 12.2 |
| RLB/LLB | Mean | -2.7 | -2.4 | -2.6 | -3.9 | -3.3 | -3.0 | -2.4 | -2.2 | -2.8 | -3.1 | -2.0 | -2.7 | -2.8 |
| | Median | -2.6 | -2.5 | -2.5 | -3.9 | -3.5 | -3.0 | -2.2 | -2.0 | -2.9 | -3.4 | -2.7 | -2.9 | -2.8 |
| | Max | 8.2 | 7.8 | 8.8 | 6.9 | 7.1 | 7.0 | 6.8 | 5.0 | 9.0 | 5.2 | 8.1 | 4.9 | 9.0 |
| | Min | -14.4 | -13.4 | -16.5 | -18.2 | -11.6 | -14.6 | -8.9 | -11.5 | -11.7 | -9.4 | -9.8 | -13.1 | -18.2 |
| | ROM | 22.6 | 21.2 | 25.3 | 25.2 | 18.7 | 21.6 | 15.8 | 16.5 | 20.7 | 14.6 | 17.9 | 18.0 | 27.2 |
| | ISV | 3.5 | 3.3 | 3.1 | 3.0 | 3.0 | 3.2 | 2.3 | 2.6 | 2.4 | 2.8 | 3.4 | 2.4 | 3.0 |
| | Below Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Neutral | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| | Above Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| RAR/LAR | Mean | -0.2 | -0.1 | -0.2 | -0.3 | -0.7 | 0.1 | -1.0 | 0.1 | -0.4 | -0.2 | -1.4 | -0.3 | -0.3 |
| | Median | -0.1 | 0.0 | 0.0 | -0.2 | -0.3 | 0.3 | -0.9 | 0.2 | -0.5 | -0.2 | -1.2 | -0.3 | -0.2 |
| | Max | 11.7 | 11.1 | 16.7 | 8.1 | 8.0 | 11.9 | 8.2 | 8.4 | 15.8 | 9.4 | 6.5 | 9.6 | 16.7 |
| | Min | -13.5 | -8.9 | -11.8 | -12.0 | -8.7 | -10.3 | -8.6 | -8.4 | -14.1 | -10.4 | -10.6 | -11.8 | -14.1 |
| | ROM | 25.2 | 20.0 | 28.6 | 20.1 | 16.7 | 22.2 | 16.7 | 16.8 | 30.0 | 19.8 | 17.1 | 21.4 | 30.9 |
| | ISV | 2.8 | 3.0 | 2.6 | 3.0 | 2.7 | 2.7 | 2.6 | 2.4 | 2.6 | 2.5 | 2.5 | 2.7 | 2.7 |
| | Below Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Neutral | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| | Above Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

## Appendix E.7: Conductor 7

Table E.7.1: Conductor 7, Neck.

| Rotation | Outcome Variable | Sample # 03 | 05 | 06 | 10 | 13 | 15 | 17 | 19 | 21 | Overall |
|---|---|---|---|---|---|---|---|---|---|---|---|
| F/E | Mean | 13.9 | 10.3 | 13.2 | 12.6 | 16.4 | 18.8 | 18.2 | 17.7 | 20.7 | 16.2 |
| | Median | 16.6 | 14.1 | 16.1 | 14.3 | 17.8 | 21.0 | 21.2 | 20.0 | 22.3 | 18.6 |
| | Max | 37.6 | 30.4 | 36.8 | 37.3 | 31.1 | 42.2 | 38.7 | 33.7 | 35.5 | 42.2 |
| | Min | -20.6 | -17.0 | -23.2 | -22.4 | -15.9 | -21.7 | -22.9 | -23.9 | -20.7 | -23.9 |
| | ROM | 58.2 | 47.3 | 60.0 | 59.7 | 47.1 | 63.9 | 61.6 | 57.6 | 56.2 | 66.1 |
| | ISV | 9.9 | 11.2 | 11.9 | 10.4 | 7.2 | 9.5 | 10.0 | 9.7 | 9.7 | 10.4 |
| | Below Neutral | 11.5 | 20.5 | 15.6 | 14.3 | 37.3 | 6.5 | 7.5 | 8.9 | 5.0 | 9.8 |
| | Neutral | 14.5 | 19.3 | 12.6 | 18.4 | 11.1 | 6.6 | 8.7 | 6.3 | 5.5 | 10.9 |
| | Above Neutral | 74.0 | 60.1 | 71.7 | 67.2 | 85.1 | 86.9 | 83.8 | 84.8 | 89.5 | 79.3 |
| RLB/LLB | Mean | -1.0 | -0.8 | -1.4 | -0.8 | 0.9 | -0.8 | -2.2 | -1.5 | -2.4 | -1.2 |
| | Median | -0.3 | -0.5 | -0.7 | -0.6 | 1.5 | -0.8 | -2.3 | -1.5 | -2.1 | -0.9 |
| | Max | 9.2 | 15.6 | 10.5 | 17.6 | 14.7 | 10.8 | 9.6 | 12.4 | 14.4 | 17.6 |
| | Min | -20.0 | -16.3 | -16.9 | -16.1 | -8.3 | -16.6 | -15.8 | -13.4 | -14.8 | -20.0 |
| | ROM | 29.1 | 31.9 | 27.4 | 33.7 | 23.0 | 27.4 | 25.4 | 25.8 | 29.2 | 37.5 |
| | ISV | 4.4 | 5.3 | 4.6 | 4.6 | 3.2 | 3.5 | 4.3 | 4.1 | 4.1 | 4.3 |
| | Below Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Neutral | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| | Above Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| RAR/LAR | Mean | -1.0 | -0.8 | -1.4 | -0.8 | 0.9 | -0.8 | -2.2 | -1.5 | -2.4 | -1.2 |
| | Median | -0.3 | -0.5 | -0.7 | -0.6 | 1.5 | -0.8 | -2.3 | -1.5 | -2.1 | -0.9 |
| | Max | 9.2 | 15.6 | 10.5 | 17.6 | 14.7 | 10.8 | 9.6 | 12.4 | 14.4 | 17.6 |
| | Min | -20.0 | -16.3 | -16.9 | -16.1 | -8.3 | -16.6 | -15.8 | -13.4 | -14.8 | -20.0 |
| | ROM | 29.1 | 31.9 | 27.4 | 33.7 | 23.0 | 27.4 | 25.4 | 25.8 | 29.2 | 37.5 |
| | ISV | 4.4 | 5.3 | 4.6 | 4.6 | 3.2 | 3.5 | 4.3 | 4.1 | 4.1 | 4.3 |
| | Below Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Neutral | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| | Above Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

Table E.7.2: Conductor 7, Shoulder.

| Rotation | Outcome Variables | | Sample # 03 | 05 | 06 | 10 | 13 | 15 | 17 | 19 | 21 | Overall |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F/E | Right | Mean | 41.7 | 42.9 | 45.1 | 44.0 | 35.6 | 45.9 | 46.4 | 45.7 | 50.8 | 44.7 |
| | | Median | 40.1 | 41.7 | 44.4 | 43.9 | 34.5 | 44.1 | 44.7 | 45.0 | 48.6 | 43.1 |
| | | Max | 94.1 | 86.4 | 99.7 | 102.7 | 75.6 | 105.2 | 105.1 | 95.0 | 114.3 | 114.3 |
| | | Min | 9.5 | -10.4 | -5.7 | -17.2 | 9.1 | 4.6 | -12.5 | -2.5 | 5.9 | -17.2 |
| | | ROM | 84.6 | 96.8 | 105.4 | 119.9 | 66.6 | 100.7 | 117.6 | 97.5 | 108.4 | 131.5 |
| | | ISV | 10.6 | 12.5 | 13.8 | 16.5 | 10.3 | 15.5 | 16.5 | 13.3 | 17.2 | 14.8 |
| | | Below Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Neutral | 0.6 | 2.0 | 1.6 | 6.1 | 3.1 | 2.4 | 3.1 | 1.2 | 1.9 | 2.4 |
| | | Above Neutral | 99.4 | 98.0 | 98.4 | 94.0 | 96.9 | 97.6 | 97.9 | 98.8 | 98.1 | 97.6 |
| | Left | Mean | 24.1 | 29.7 | 25.6 | 24.8 | 17.0 | 28.7 | 29.9 | 27.8 | 34.0 | 27.2 |
| | | Median | 18.9 | 27.1 | 23.2 | 19.6 | 14.5 | 26.2 | 26.2 | 22.3 | 32.6 | 23.2 |
| | | Max | 90.3 | 83.5 | 86.1 | 97.0 | 55.6 | 90.2 | 77.7 | 94.2 | 88.2 | 97.0 |
| | | Min | -12.2 | -9.8 | -40.9 | -23.6 | -8.5 | -16.0 | -11.2 | -10.2 | -21.3 | -40.9 |
| | | ROM | 102.5 | 93.3 | 127.0 | 120.6 | 64.2 | 106.3 | 88.9 | 104.4 | 109.5 | 138.0 |
| | | ISV | 21.2 | 20.7 | 21.3 | 21.2 | 12.8 | 20.5 | 19.9 | 18.5 | 20.8 | 20.5 |
| | | Below Neutral | 0.0 | 0.0 | 1.7 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 |
| | | Neutral | 51.5 | 38.4 | 43.1 | 50.5 | 61.4 | 39.6 | 38.7 | 43.0 | 33.2 | 44.0 |
| | | Above Neutral | 48.4 | 61.6 | 55.3 | 49.4 | 38.6 | 60.4 | 61.3 | 57.0 | 66.8 | 55.8 |
| ABD/ADD | Right | Mean | 22.7 | 24.6 | 25.6 | 25.2 | 30.1 | 24.5 | 29.3 | 22.9 | 25.0 | 25.0 |
| | | Median | 20.9 | 22.5 | 23.1 | 22.9 | 28.9 | 22.6 | 27.4 | 21.2 | 22.6 | 22.9 |
| | | Max | 68.0 | 54.8 | 71.6 | 79.4 | 58.7 | 63.1 | 79.5 | 57.3 | 69.8 | 79.5 |
| | | Min | -1.1 | 1.2 | -3.1 | -11.6 | 0.5 | -21.3 | 2.2 | -13.1 | -8.5 | -21.3 |
| | | ROM | 69.1 | 53.6 | 74.6 | 91.0 | 58.2 | 84.4 | 77.4 | 70.4 | 78.3 | 100.8 |
| | | ISV | 8.5 | 9.7 | 11.7 | 13.2 | 9.3 | 12.0 | 11.7 | 9.8 | 13.1 | 11.5 |
| | | Below Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Neutral | 44.1 | 35.0 | 36.3 | 39.1 | 11.2 | 39.8 | 24.8 | 43.6 | 39.2 | 37.2 |
| | | Above Neutral | 55.9 | 65.0 | 63.7 | 60.9 | 88.9 | 60.2 | 75.2 | 56.4 | 60.8 | 62.8 |
| | Left | Mean | 23.0 | 21.2 | 25.0 | 23.7 | 22.3 | 24.5 | 24.3 | 22.6 | 25.6 | 23.8 |
| | | Median | 22.4 | 20.4 | 23.8 | 22.9 | 22.3 | 23.7 | 23.2 | 21.9 | 24.2 | 22.9 |
| | | Max | 56.3 | 42.3 | 64.0 | 70.8 | 42.0 | 61.7 | 63.2 | 57.6 | 72.6 | 72.6 |
| | | Min | -7.4 | -2.3 | 6.2 | -20.0 | 9.3 | -17.2 | -0.9 | 0.7 | 0.2 | -20.0 |
| | | ROM | 63.8 | 44.6 | 57.8 | 90.9 | 32.7 | 78.9 | 64.1 | 56.9 | 72.4 | 92.7 |
| | | ISV | 6.4 | 6.0 | 7.4 | 9.1 | 5.2 | 8.2 | 7.2 | 6.7 | 8.2 | 7.6 |
| | | Below Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Neutral | 28.8 | 46.5 | 24.5 | 32.6 | 35.7 | 28.7 | 25.0 | 25.0 | 21.3 | 29.6 |
| | | Above Neutral | 71.2 | 53.5 | 75.6 | 67.4 | 64.3 | 71.3 | 75.0 | 65.0 | 78.7 | 70.4 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IR/ER | Right | Mean | 7.2 | 7.5 | 8.3 | 8.8 | -4.7 | 9.8 | 3.6 | 7.0 | 11.7 | 7.5 |
| | | Median | 6.9 | 7.8 | 7.1 | 9.2 | -5.2 | 8.6 | 2.5 | 6.4 | 9.7 | 6.9 |
| | | Max | 52.8 | 42.4 | 60.9 | 67.6 | 29.7 | 67.9 | 61.1 | 58.2 | 75.3 | 75.3 |
| | | Min | -27.9 | -24.8 | -37.4 | -35.6 | -29.2 | -24.8 | -48.3 | -36.8 | -34.1 | -48.3 |
| | | ROM | 80.7 | 67.2 | 98.3 | 103.2 | 58.8 | 92.6 | 109.4 | 95.0 | 109.4 | 123.6 |
| | | ISV | 10.0 | 10.4 | 12.9 | 13.5 | 10.1 | 14.0 | 15.2 | 10.9 | 15.0 | 13.3 |
| | | Below Neutral | 0.2 | 0.3 | 0.4 | 1.3 | 4.9 | 0.4 | 5.3 | 0.2 | 0.9 | 1.2 |
| | | Neutral | 90.3 | 90.2 | 81.2 | 82.4 | 93.9 | 77.5 | 80.5 | 88.0 | 72.5 | 83.0 |
| | | Above Neutral | 0.5 | 0.5 | 18.4 | 16.2 | 1.2 | 22.2 | 14.2 | 11.8 | 26.6 | 15.7 |
| | Left | Mean | 6.4 | 9.7 | 6.6 | 8.5 | 2.9 | 8.1 | 9.9 | 11.4 | 11.5 | 8.5 |
| | | Median | 2.9 | 7.5 | 3.7 | 5.9 | 1.9 | 6.9 | 8.2 | 9.7 | 11.4 | 6.6 |
| | | Max | 62.8 | 52.2 | 61.0 | 61.7 | 29.9 | 63.4 | 55.1 | 53.9 | 61.4 | 63.4 |
| | | Min | -25.1 | -23.6 | -28.1 | -34.3 | -18.8 | -40.6 | -34.4 | -28.1 | -37.5 | -40.6 |
| | | ROM | 87.9 | 75.7 | 89.1 | 96.1 | 48.7 | 104.0 | 89.5 | 82.0 | 98.9 | 104.0 |
| | | ISV | 16.1 | 15.4 | 15.9 | 16.5 | 9.3 | 15.8 | 14.6 | 13.1 | 15.3 | 15.4 |
| | | Below Neutral | 0.8 | 0.9 | 2.0 | 1.3 | 0.0 | 1.6 | 0.7 | 0.1 | 1.1 | 1.0 |
| | | Neutral | 77.7 | 72.7 | 76.7 | 77.3 | 94.1 | 77.9 | 74.7 | 76.6 | 65.6 | 76.5 |
| | | Above Neutral | 21.5 | 26.4 | 21.4 | 21.4 | 5.9 | 20.6 | 24.6 | 23.3 | 33.3 | 22.4 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

Table E.7.3: Conductor 7, Elbow.

| Rotation | Outcome Variable | | Sample # 03 | 05 | 06 | 10 | 13 | 15 | 17 | 19 | 21 | Overall |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F/E | Right | Mean | 67.4 | 67.4 | 65.6 | 67.7 | 75.7 | 67.9 | 71.0 | 72.8 | 61.8 | 88.4 |
| | | Median | 65.3 | 65.4 | 62.0 | 66.7 | 77.6 | 64.8 | 68.9 | 71.3 | 59.6 | 89.7 |
| | | Max | 125.5 | 127.5 | 129.7 | 129.5 | 123.4 | 134.1 | 128.7 | 130.0 | 127.4 | 145.4 |
| | | Min | -0.5 | -8.4 | -1.7 | -5.2 | -1.3 | -11.8 | -5.6 | -10.4 | 4.0 | -5.3 |
| | | ROM | 126.0 | 135.9 | 131.4 | 134.7 | 124.7 | 145.9 | 134.3 | 140.4 | 123.4 | 150.7 |
| | | ISV | 20.3 | 21.7 | 24.0 | 24.2 | 21.3 | 23.1 | 22.7 | 20.8 | 22.2 | 18.7 |
| | | Below Neutral | 39.3 | 40.2 | 47.0 | 38.6 | 26.2 | 42.0 | 34.3 | 28.6 | 50.9 | 7.7 |
| | | Neutral | 53.5 | 51.3 | 42.6 | 51.7 | 60.7 | 47.1 | 53.5 | 60.9 | 42.4 | 67.6 |
| | | Above Neutral | 7.2 | 8.5 | 10.4 | 9.7 | 13.1 | 11.0 | 12.2 | 10.5 | 6.7 | 24.7 |
| | Left | Mean | 63.2 | 62.6 | 62.0 | 59.5 | 57.9 | 68.4 | 70.7 | 65.8 | 66.9 | 64.8 |
| | | Median | 60.8 | 64.3 | 60.6 | 59.0 | 63.8 | 69.4 | 71.7 | 67.8 | 65.5 | 65.2 |
| | | Max | 144.9 | 114.9 | 127.5 | 143.5 | 123.1 | 147.4 | 139.1 | 128.0 | 129.9 | 147.4 |
| | | Min | 0.1 | -2.5 | -18.9 | -4.9 | -2.5 | -7.3 | -1.5 | -9.3 | 8.7 | -18.9 |
| | | ROM | 144.8 | 117.4 | 146.4 | 148.4 | 125.6 | 154.7 | 140.6 | 137.3 | 121.2 | 166.3 |
| | | ISV | 23.1 | 22.0 | 26.0 | 31.5 | 32.8 | 29.4 | 23.1 | 25.3 | 20.9 | 26.7 |
| | | Below Neutral | 48.5 | 41.9 | 49.1 | 51.1 | 45.9 | 35.9 | 31.5 | 37.8 | 39.9 | 42.1 |
| | | Neutral | 45.0 | 54.0 | 42.2 | 38.3 | 46.1 | 50.5 | 58.2 | 53.9 | 52.0 | 48.6 |
| | | Above Neutral | 6.5 | 4.1 | 8.7 | 10.6 | 8.0 | 13.7 | 19.3 | 8.3 | 8.1 | 9.4 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

Table E.7.4: Conductor 7, Wrist.

| Rotation | Outcome Variable | | Sample # 03 | 05 | 06 | 10 | 13 | 15 | 17 | 19 | 21 | Overall |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F/E | Right | Mean | -27.3 | -25.3 | -24.7 | -24.5 | -25.9 | -26.3 | -23.3 | -25.6 | -26.0 | -25.6 |
| | | Median | -29.3 | -28.0 | -27.9 | -27.1 | -27.4 | -28.1 | -26.1 | -27.2 | -28.2 | -27.8 |
| | | Max | 5.9 | 27.8 | 23.5 | 20.2 | 13.5 | 28.3 | 22.4 | 33.5 | 18.3 | 33.5 |
| | | Min | -43.4 | -40.4 | -41.1 | -42.6 | -42.4 | -41.0 | -41.4 | -42.1 | -39.7 | -43.4 |
| | | ROM | 49.3 | 68.2 | 64.6 | 62.8 | 55.9 | 69.3 | 63.8 | 75.6 | 58.0 | 76.9 |
| | | ISV | 7.2 | 9.2 | 9.5 | 10.2 | 8.9 | 7.8 | 9.3 | 8.7 | 8.8 | 8.8 |
| | | Below Neutral | 99.5 | 97.3 | 96.1 | 95.2 | 96.4 | 98.2 | 96.0 | 97.3 | 96.3 | 97.2 |
| | | Neutral | 0.5 | 1.9 | 2.6 | 3.9 | 2.6 | 1.3 | 3.3 | 1.7 | 2.8 | 2.1 |
| | | Above Neutral | 0.0 | 0.7 | 1.2 | 0.9 | 1.0 | 0.5 | 0.7 | 1.0 | 0.9 | 0.7 |
| | Left | Mean | -12.0 | -12.2 | -10.0 | -12.0 | -10.6 | -11.8 | -12.0 | -13.5 | -12.7 | -12.0 |
| | | Median | -11.0 | -13.3 | -11.2 | -11.7 | -10.8 | -12.5 | -12.8 | -14.7 | -13.1 | -12.4 |
| | | Max | 18.3 | 15.4 | 26.4 | 25.1 | 9.3 | 20.5 | 18.7 | 25.2 | 19.3 | 26.4 |
| | | Min | -32.7 | -29.0 | -34.2 | -38.6 | -31.1 | -34.9 | -33.1 | -40.5 | -34.4 | -40.5 |
| | | ROM | 51.0 | 44.3 | 60.5 | 63.8 | 40.4 | 55.5 | 51.7 | 65.6 | 53.7 | 66.8 |
| | | ISV | 8.3 | 8.0 | 9.1 | 8.4 | 7.9 | 8.4 | 7.6 | 7.6 | 7.5 | 8.2 |
| | | Below Neutral | 74.0 | 29.8 | 71.2 | 78.4 | 73.6 | 76.7 | 77.6 | 83.6 | 82.7 | 77.5 |
| | | Neutral | 25.6 | 17.5 | 5.4 | 20.2 | 25.8 | 20.9 | 21.7 | 16.0 | 16.5 | 21.2 |
| | | Above Neutral | 3.7 | 2.7 | 3.4 | 1.3 | 0.6 | 2.5 | 0.7 | 0.4 | 0.8 | 1.4 |
| RD/UD | Right | Mean | 9.6 | 15.3 | 13.5 | 12.6 | 14.1 | 12.6 | 14.5 | 12.3 | 12.9 | 12.6 |
| | | Median | 10.7 | 17.1 | 14.6 | 14.2 | 15.9 | 13.8 | 15.8 | 13.8 | 14.5 | 13.8 |
| | | Max | 28.7 | 29.6 | 33.3 | 32.3 | 32.3 | 32.5 | 32.7 | 30.6 | 32.3 | 33.3 |
| | | Min | -41.4 | -31.7 | -38.9 | -38.7 | -26.8 | -41.5 | -34.5 | -36.0 | -35.5 | -41.5 |
| | | ROM | 70.1 | 61.4 | 72.2 | 70.9 | 59.1 | 74.0 | 67.1 | 66.6 | 67.8 | 74.8 |
| | | ISV | 8.2 | 8.1 | 9.8 | 9.7 | 8.5 | 9.5 | 9.9 | 10.2 | 10.2 | 9.6 |
| | | Below Neutral | 5.0 | 2.6 | 5.1 | 5.0 | 2.2 | 4.5 | 4.3 | 6.2 | 5.9 | 4.8 |
| | | Neutral | 19.9 | 8.2 | 19.8 | 14.2 | 14.6 | 12.7 | 10.0 | 13.1 | 9.7 | 13.3 |
| | | Above Neutral | 75.1 | 89.3 | 84.2 | 80.9 | 83.2 | 82.8 | 85.7 | 80.7 | 84.4 | 81.9 |
| | Left | Mean | -8.4 | -5.9 | -7.1 | -5.7 | -2.3 | -3.6 | -5.0 | -5.2 | -6.2 | -5.6 |
| | | Median | -10.0 | -6.5 | -7.1 | -6.7 | -1.3 | -3.7 | -5.0 | -4.9 | -6.6 | -5.8 |
| | | Max | 24.9 | 24.4 | 23.7 | 32.2 | 20.2 | 28.8 | 28.8 | 29.1 | 30.5 | 32.2 |
| | | Min | -45.1 | -29.5 | -50.2 | -52.6 | -26.7 | -45.4 | -41.4 | -40.5 | -41.9 | -52.6 |
| | | ROM | 70.0 | 53.9 | 73.9 | 84.8 | 46.9 | 74.2 | 70.2 | 69.6 | 72.4 | 84.8 |
| | | ISV | 9.3 | 9.0 | 10.1 | 11.2 | 7.8 | 9.9 | 10.1 | 9.9 | 10.6 | 10.1 |
| | | Below Neutral | 65.3 | 56.3 | 59.6 | 55.7 | 31.6 | 44.6 | 49.9 | 49.4 | 58.3 | 53.1 |
| | | Neutral | 25.5 | 30.8 | 29.2 | 28.0 | 55.2 | 36.4 | 33.8 | 34.4 | 27.9 | 32.2 |
| | | Above Neutral | 9.2 | 12.9 | 11.2 | 16.2 | 13.2 | 19.0 | 16.3 | 16.1 | 13.8 | 14.6 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P/S | Right | Mean | 69.7 | 63.8 | 65.1 | 59.0 | 54.7 | 64.1 | 60.3 | 58.9 | 67.0 | 63.3 |
| | | Median | 70.2 | 63.4 | 64.7 | 59.5 | 53.9 | 64.1 | 61.1 | 59.4 | 68.3 | 63.4 |
| | | Max | 134.4 | 175.4 | 154.5 | 134.7 | 133.0 | 121.5 | 120.9 | 140.6 | 119.8 | 175.4 |
| | | Min | -5.7 | 7.1 | 8.4 | -28.7 | -1.7 | -19.7 | -11.5 | -11.7 | 1.7 | -28.7 |
| | | ROM | 140.1 | 168.3 | 146.2 | 163.4 | 134.7 | 141.1 | 132.4 | 152.3 | 118.1 | 204.1 |
| | | ISV | 14.7 | 18.4 | 16.8 | 18.2 | 12.9 | 15.3 | 15.5 | 16.3 | 15.7 | 16.5 |
| | | Below Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | | Neutral | 0.2 | 0.7 | 0.3 | 2.6 | 0.4 | 0.5 | 1.2 | 1.0 | 0.9 | 0.9 |
| | | Above Neutral | 99.8 | 99.3 | 99.7 | 97.4 | 99.6 | 99.5 | 98.8 | 99.0 | 99.1 | 99.1 |
| | Left | Mean | 79.7 | 70.9 | 76.5 | 80.0 | 71.2 | 66.2 | 67.9 | 67.7 | 67.4 | 72.1 |
| | | Median | 82.9 | 72.7 | 79.8 | 84.9 | 62.8 | 63.9 | 68.6 | 66.8 | 68.3 | 72.1 |
| | | Max | 150.3 | 150.8 | 162.6 | 148.2 | 139.1 | 152.8 | 134.9 | 156.4 | 136.5 | 162.6 |
| | | Min | -10.7 | -45.3 | -13.1 | -43.5 | -19.0 | -44.5 | -29.4 | -38.6 | -17.2 | -45.3 |
| | | ROM | 161.0 | 196.1 | 175.8 | 191.7 | 158.1 | 197.3 | 164.3 | 195.0 | 153.8 | 207.9 |
| | | ISV | 24.3 | 31.3 | 27.2 | 30.1 | 33.3 | 29.0 | 26.0 | 27.5 | 20.6 | 28.0 |
| | | Below Neutral | 0.0 | 3.1 | 0.0 | 1.1 | 0.0 | 1.1 | 0.3 | 0.9 | 0.0 | 0.6 |
| | | Neutral | 1.0 | 2.4 | 1.7 | 3.6 | 2.9 | 3.2 | 3.0 | 2.1 | 1.7 | 2.4 |
| | | Above Neutral | 99.0 | 94.5 | 98.3 | 95.3 | 97.1 | 95.7 | 96.7 | 97.0 | 98.3 | 97.0 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

Table E.7.5: Conductor 7, Trunk.

| Rotation | Outcome Variable | Sample # 03 | 05 | 06 | 10 | 13 | 15 | 17 | 19 | 21 | Overall |
|---|---|---|---|---|---|---|---|---|---|---|---|
| F/E | Mean | -0.8 | -1.2 | 0.2 | 0.1 | -3.5 | -0.1 | 1.1 | 2.3 | 1.0 | 0.1 |
| | Median | -1.3 | -2.2 | -0.5 | -0.5 | -4.7 | -0.4 | 0.5 | 1.7 | 0.8 | -0.4 |
| | Max | 19.9 | 12.9 | 16.8 | 20.9 | 17.3 | 14.8 | 20.4 | 25.8 | 10.2 | 25.8 |
| | Min | -12.5 | -9.9 | -9.8 | -13.1 | -12.6 | -12.5 | -9.8 | -8.6 | -9.8 | -13.1 |
| | ROM | 32.3 | 22.8 | 26.6 | 34.1 | 30.0 | 27.3 | 30.2 | 34.4 | 20.0 | 38.9 |
| | ISV | 3.8 | 4.2 | 3.9 | 4.6 | 4.2 | 3.3 | 4.3 | 4.7 | 3.0 | 4.2 |
| | Below Neutral | 8.5 | 12.7 | 4.4 | 7.7 | 47.5 | 4.6 | 2.7 | 3.1 | 1.5 | 7.6 |
| | Neutral | 85.3 | 77.3 | 83.2 | 82.1 | 48.0 | 88.5 | 80.6 | 74.3 | 88.9 | 81.7 |
| | Above Neutral | 6.1 | 1.0 | 12.4 | 10.2 | 4.5 | 6.9 | 16.7 | 22.5 | 9.6 | 10.7 |
| RLB/LLB | Mean | 0.5 | 0.8 | 1.0 | 0.5 | 1.7 | 1.4 | 2.3 | 1.7 | 1.3 | 1.2 |
| | Median | 0.6 | 1.0 | 1.5 | 0.5 | 2.1 | 1.7 | 2.7 | 2.1 | 1.6 | 1.5 |
| | Max | 9.7 | 10.8 | 12.0 | 11.1 | 8.6 | 10.2 | 9.7 | 9.6 | 12.4 | 12.4 |
| | Min | -10.6 | -7.9 | -8.9 | -9.4 | -6.6 | -10.6 | -5.9 | -14.2 | -8.5 | -14.2 |
| | ROM | 20.3 | 18.7 | 20.9 | 20.5 | 15.2 | 20.8 | 15.7 | 23.9 | 20.9 | 26.6 |
| | ISV | 2.9 | 2.9 | 3.5 | 3.1 | 2.5 | 3.3 | 2.9 | 2.8 | 3.1 | 3.1 |
| | Below Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Neutral | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| | Above Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| RAR/LAR | Mean | -0.7 | -1.6 | -1.1 | -0.3 | 0.1 | -0.8 | -0.7 | -1.7 | -0.6 | -0.8 |
| | Median | -0.7 | -1.5 | -1.3 | -0.3 | 0.2 | -0.9 | -0.6 | -1.8 | -0.7 | -0.8 |
| | Max | 5.7 | 4.5 | 5.1 | 6.9 | 6.2 | 7.3 | 5.1 | 4.6 | 6.4 | 7.3 |
| | Min | -10.2 | -7.7 | -10.5 | -10.1 | -5.6 | -9.1 | -10.1 | -21.6 | -10.8 | -21.6 |
| | ROM | 15.9 | 12.1 | 15.6 | 17.0 | 11.7 | 16.4 | 15.2 | 26.1 | 17.2 | 28.9 |
| | ISV | 1.9 | 1.8 | 1.9 | 2.4 | 1.6 | 2.1 | 1.9 | 2.3 | 2.3 | 2.1 |
| | Below Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 |
| | Neutral | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 99.9 | 100.0 | 100.0 |
| | Above Neutral | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.0 | 0.0 |

Abbreviations: Minimum (min), maximum (max), range of motion (ROM), intra-subject variability (ISV), flexion (F), extension (E), abduction (ABD), adduction (ADD), radial deviation (RD), ulnar deviation (UD), right lateral bending (RLB), left lateral bending (LLB), axial rotation (AR), internal rotation (IR), external rotation (ER), pronation (P), supination (S). Negative joint angles represent E, ADD, ER, LLB, LAR, S, and UD.

## Appendix F: Time series graphs

## Appendix F.1: Conductor 1

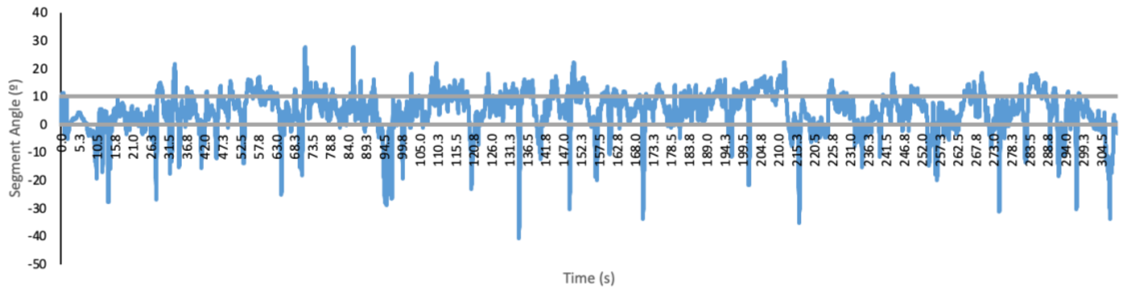



*Figure F.1.1 C01-03 Neck flexion time series with neutral ROM in grey*

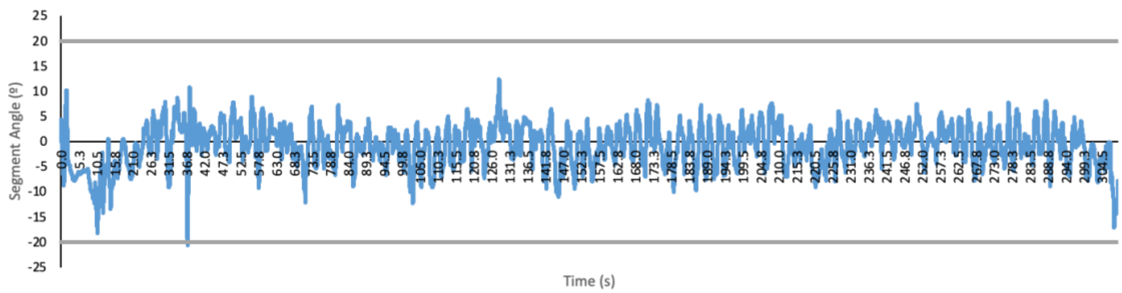



*Figure F.1.2 C01-03 Neck lateral bending time series with neutral ROM in grey*

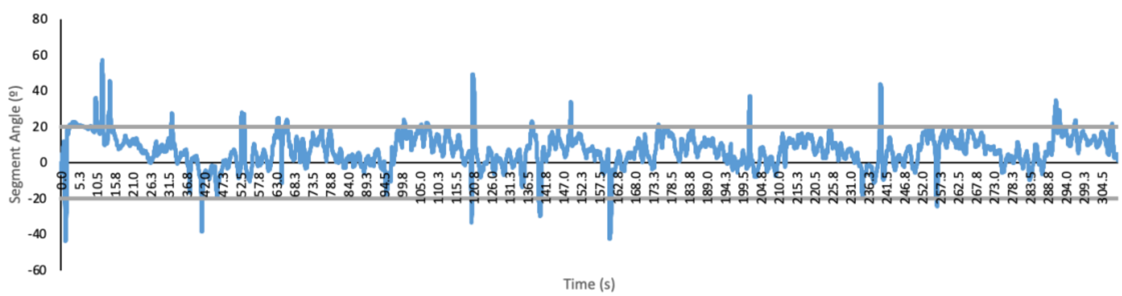



*Figure F.1.3 C01-03 Neck axial rotation time series with neutral ROM in grey*

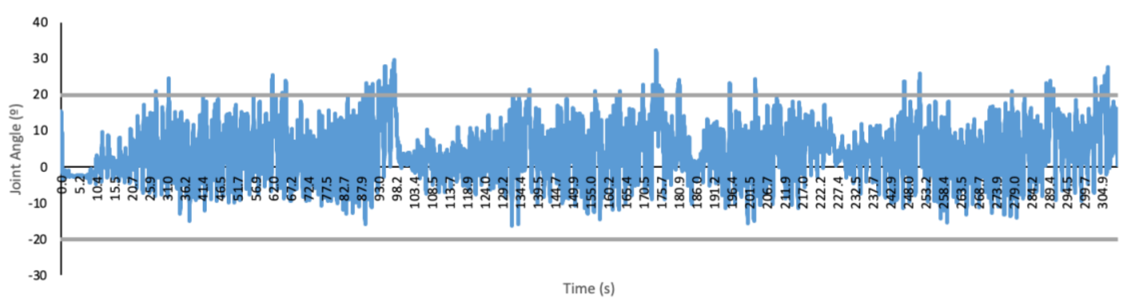



*Figure F.1.4 C01-03 Right shoulder flexion time series with neutral ROM in grey*

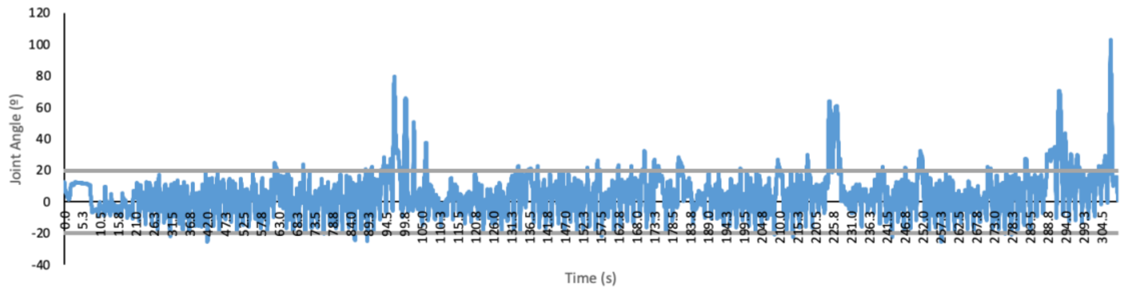



*Figure F.1.5 C01-03 Left shoulder flexion time series with neutral ROM in grey*

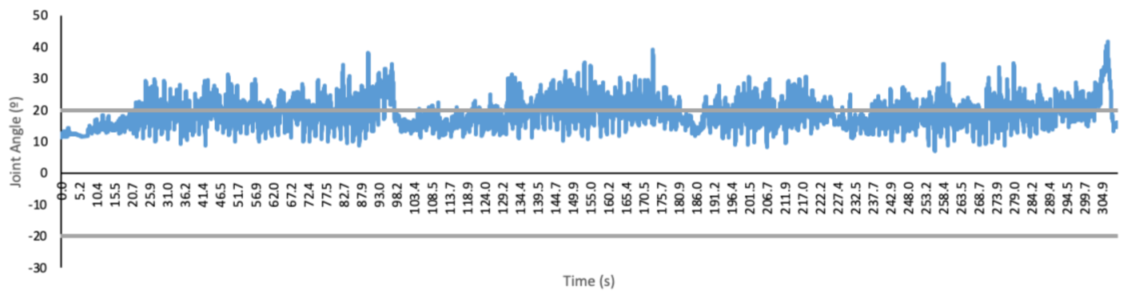



*Figure F.1.6 C01-03 Right shoulder abduction time series with neutral ROM in grey*

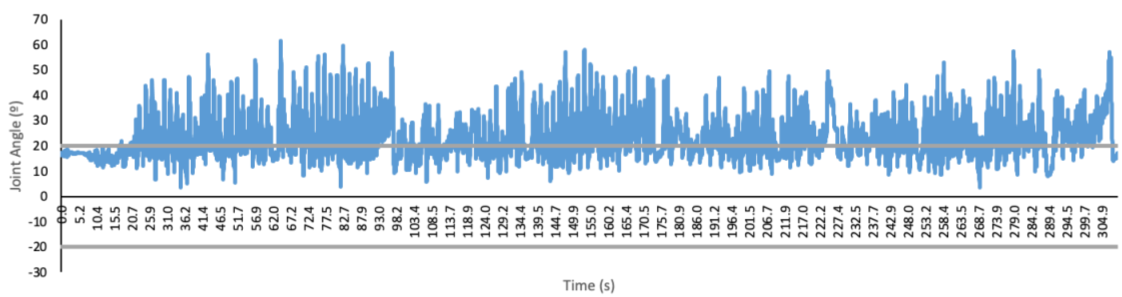



*Figure F.1.7 C01-03 Left shoulder abduction time series with neutral ROM in grey*

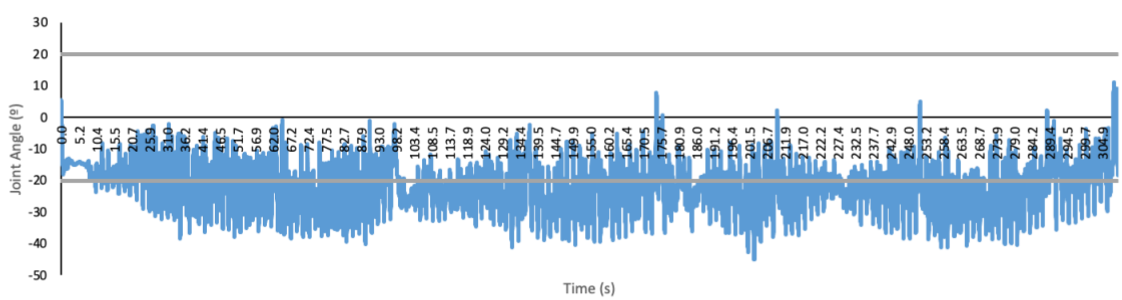



*Figure F.1.8 C01-03 Right shoulder rotation time series with neutral ROM in grey*

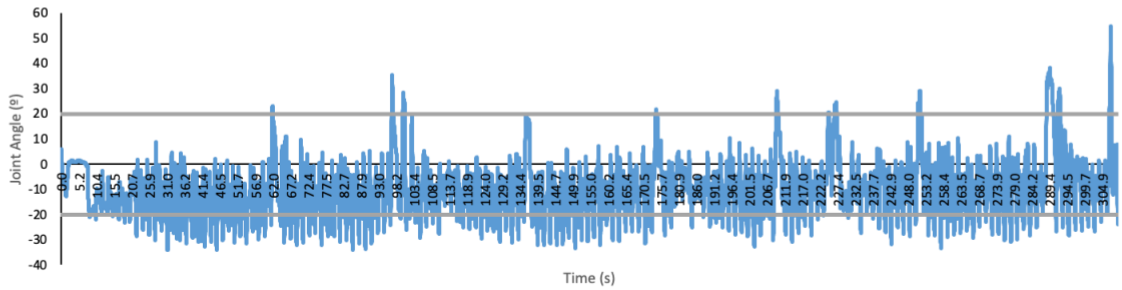



*Figure F.1.9 C01-03 Left shoulder rotation time series with neutral ROM in grey*

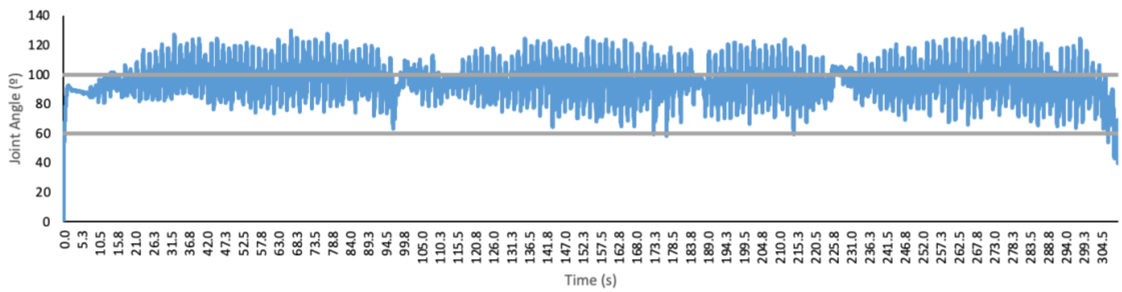



*Figure F.1.10 C01-03 Right elbow flexion time series with neutral ROM in grey*

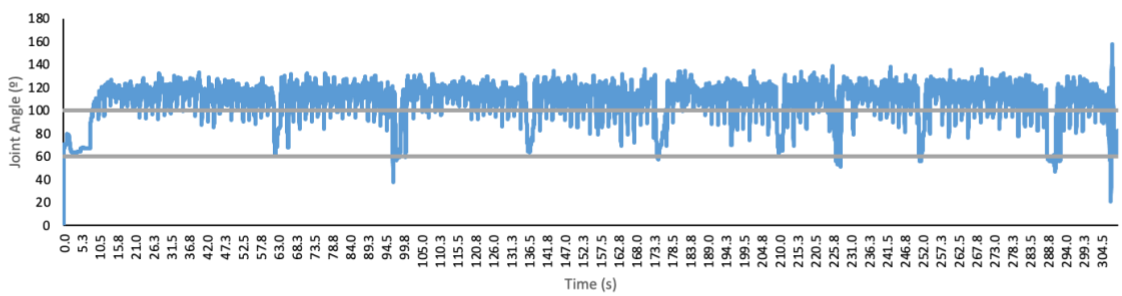



*Figure F.1.11 C01-03 Left elbow flexion time series with neutral ROM in grey*

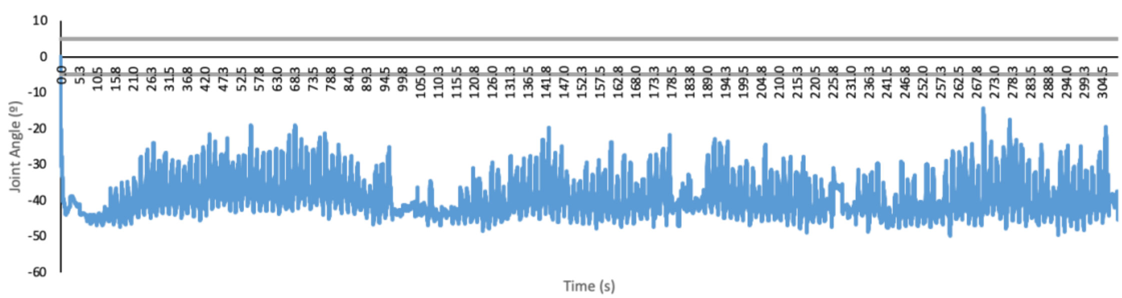



*Figure F.1.12 C01-03 Right wrist flexion time series with neutral ROM in grey*

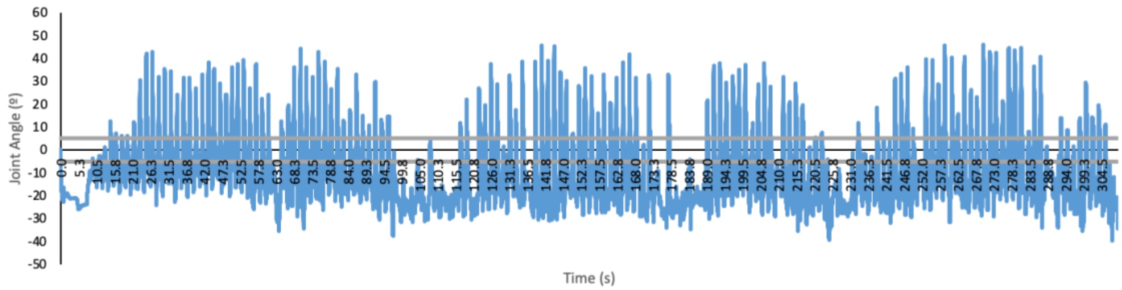



*Figure F.1.13 C01-03 Left wrist flexion time series with neutral ROM in grey*

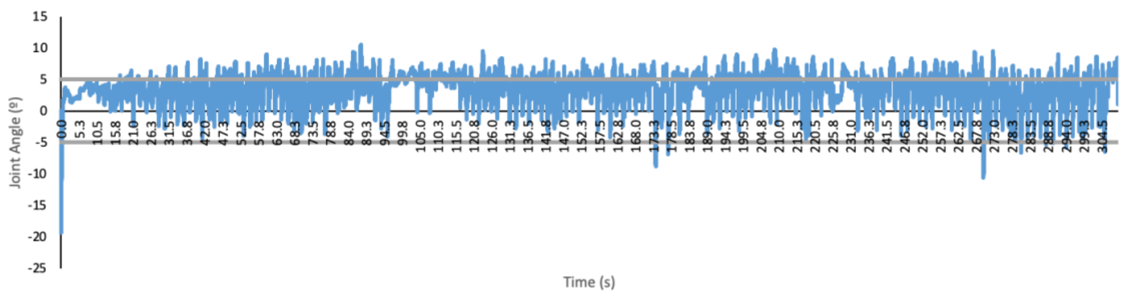



*Figure F.1.14 C01-03 Right wrist radial deviation time series with neutral ROM in grey*

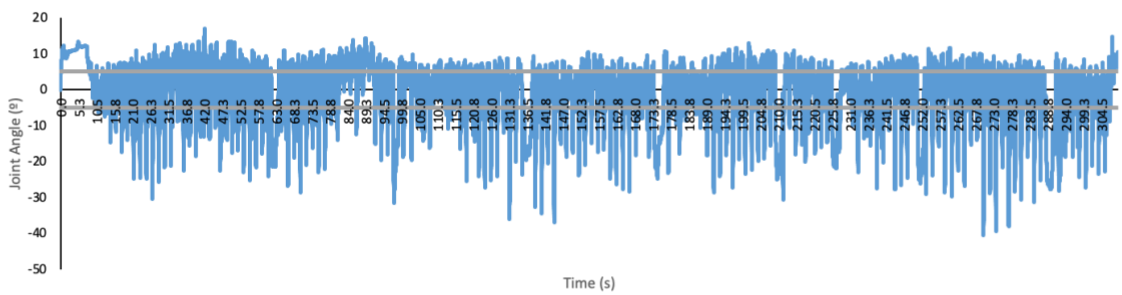



*Figure F.1.15 C01-03 Left wrist radial deviation time series with neutral ROM in grey*

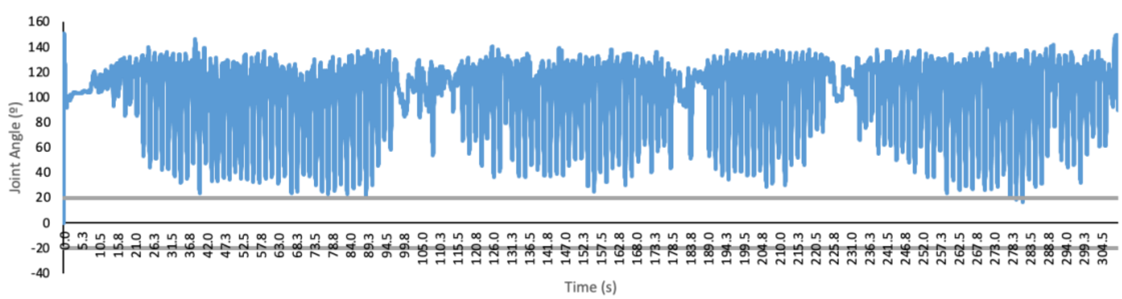



*Figure F.1.16C01-03 Right wrist pronation time series with neutral ROM in grey*

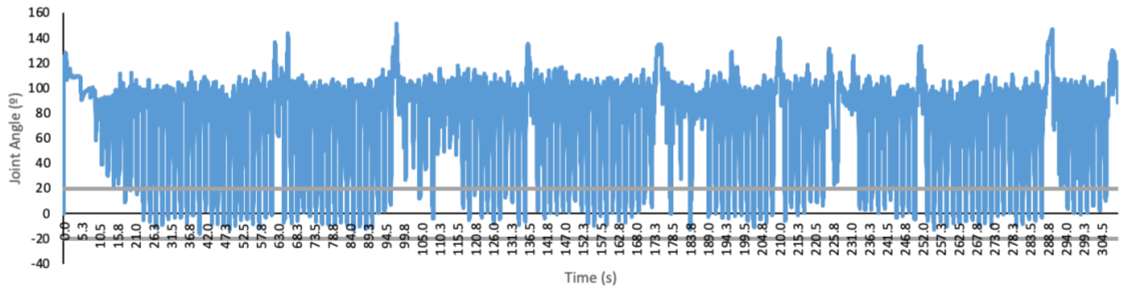



*Figure F.1.17 C01-03 Left wrist pronation time series with neutral ROM in grey*

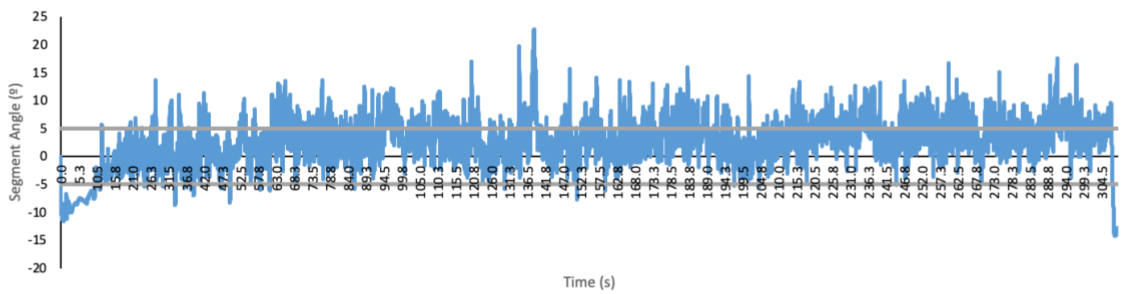



*Figure F.1.18 C01-03 Trunk flexion time series with neutral ROM in grey*

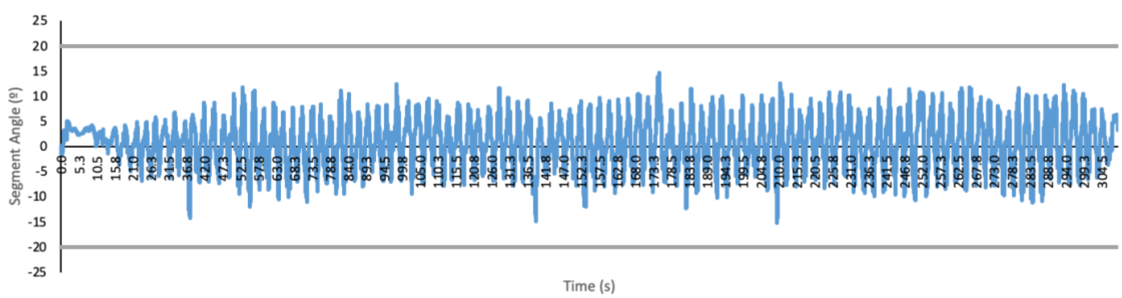



*Figure F.1.19 C01-03 Trunk lateral bending time series with neutral ROM in grey*

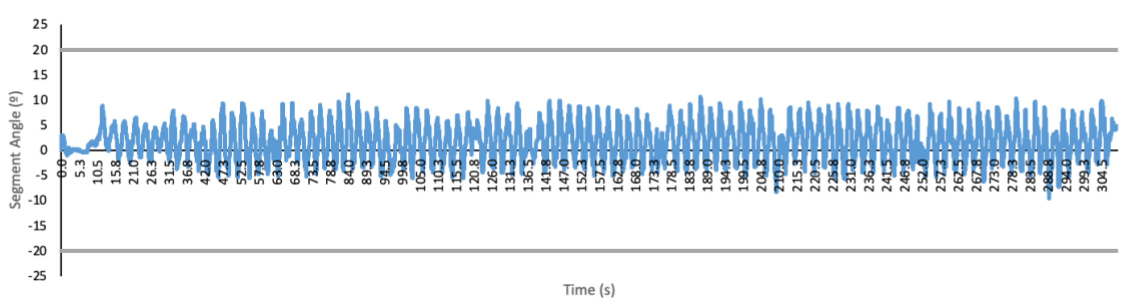



*Figure F.1.20 01-03 Trunk axial rotation time series with neutral ROM in grey*

## Appendix F.2: Conductor 2

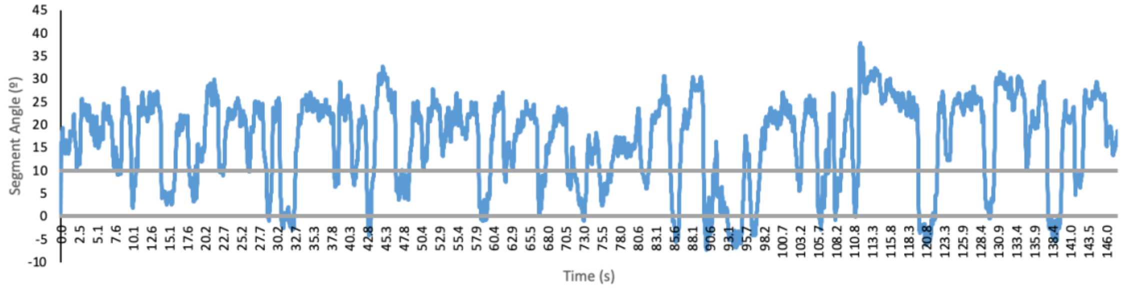



*Figure F.2.1 C02-17 Neck flexion time series with neutral ROM in grey*

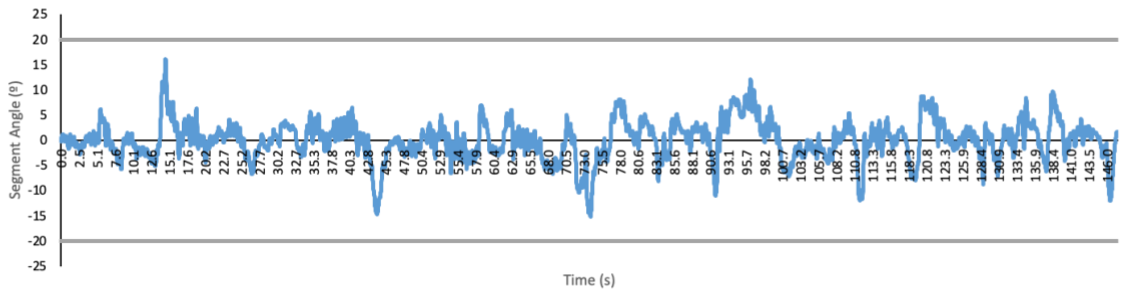



*Figure F.2.2 C02-17 Neck lateral bending time series with neutral ROM in grey*

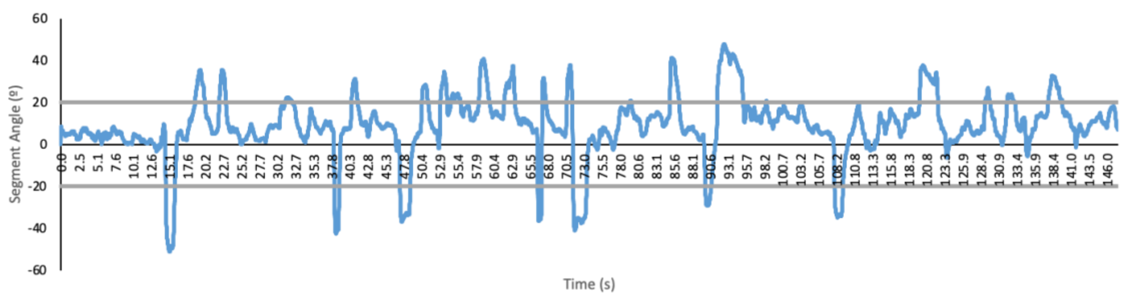



*Figure F.2.3 C02-17 Neck axial rotation time series with neutral ROM in grey*

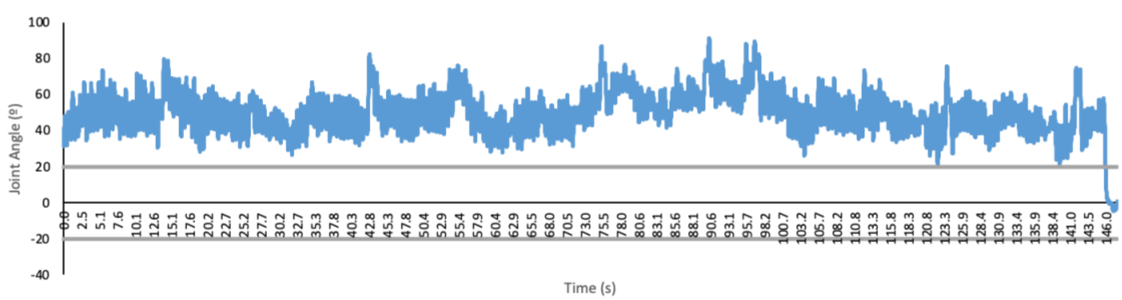



*Figure F.2.4 C02-17 Right shoulder flexion time series with neutral ROM in grey*

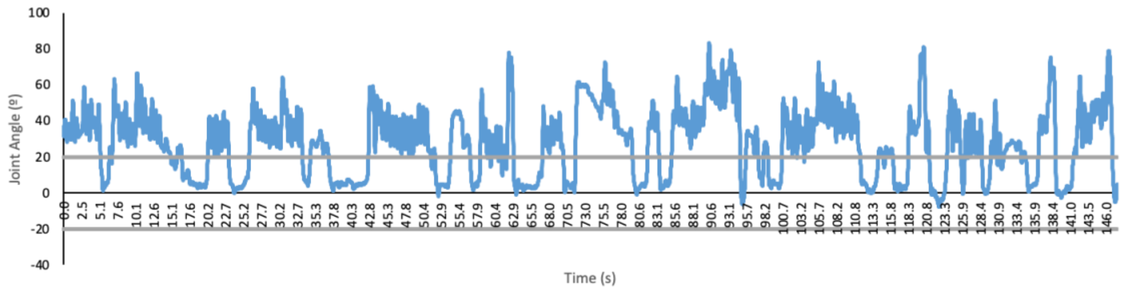



*Figure F.2.5 C02-17 Left shoulder flexion time series with neutral ROM in grey*

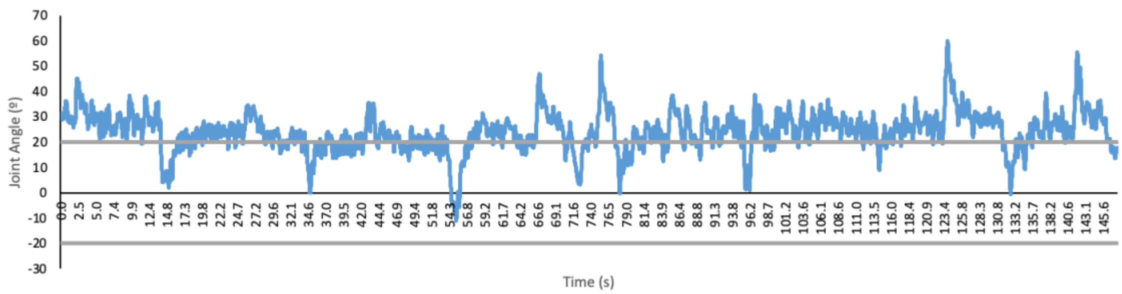



*Figure F.2.6 C02-17 Right shoulder abduction time series with neutral ROM in grey*

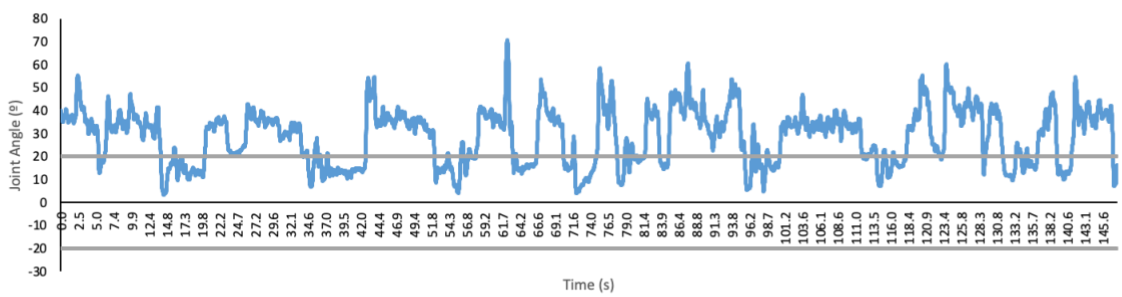



*Figure F.2.7 C02-17 Left shoulder abduction time series with neutral ROM in grey*

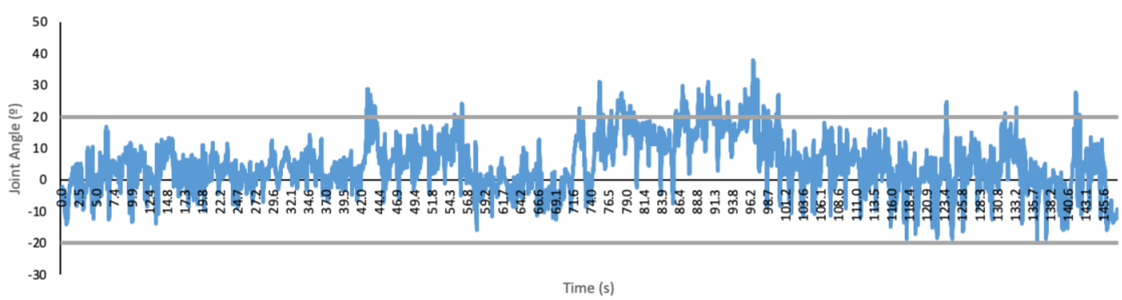



*Figure F..8 C02-17 Right shoulder rotation time series with neutral ROM in grey*

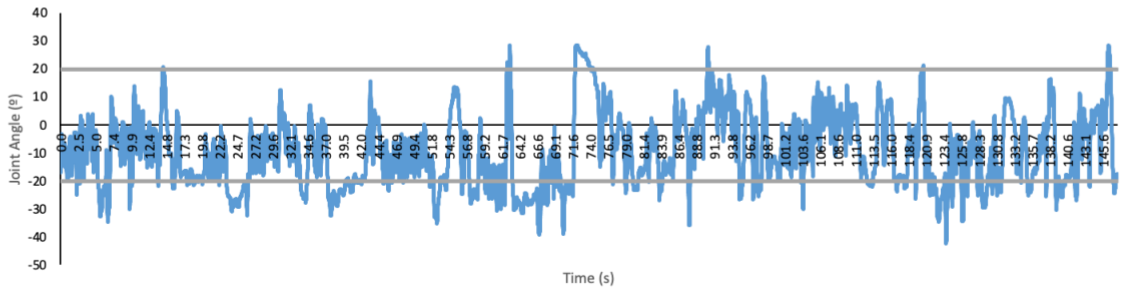



*Figure F.2.9 C02-17 Left shoulder rotation time series with neutral ROM in grey*

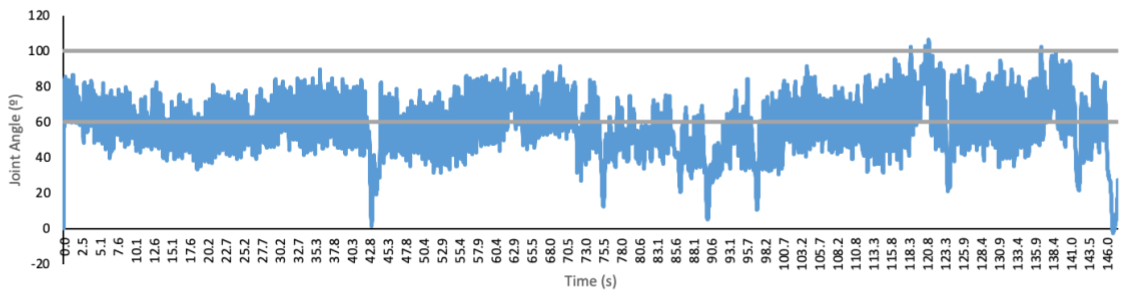



*Figure F.2.10 C02-17 Right elbow flexion time series with neutral ROM in grey*

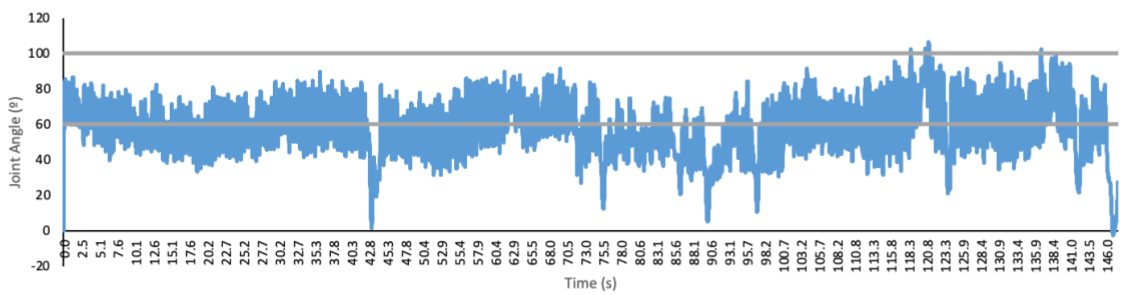



*Figure F.2.11 C02-17 Left elbow flexion time series with neutral ROM in grey*

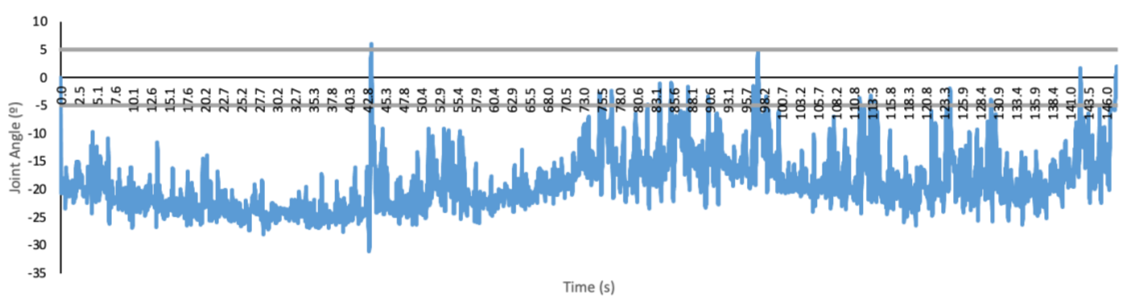



*Figure F.2.12 C02-17 Right wrist flexion time series with neutral ROM in grey*

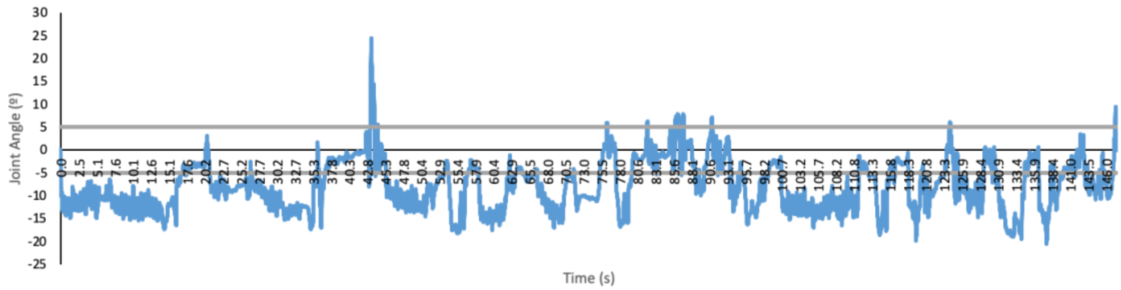



*Figure F.2.13 C02-17 Left wrist flexion time series with neutral ROM in grey*

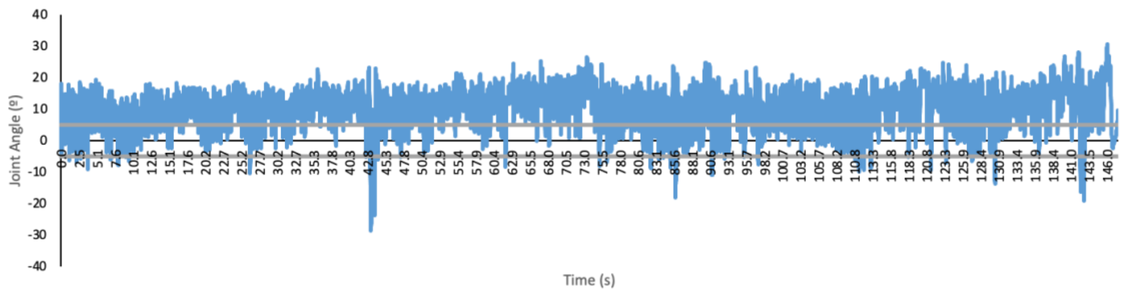



*Figure F.2.14 C02-17 Right wrist radial deviation time series with neutral ROM in grey*

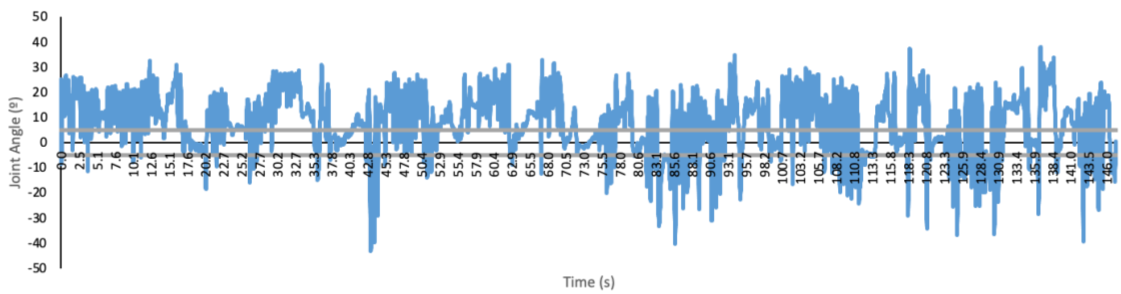



*Figure F.2.15 C02-17 Left wrist radial deviation time series with neutral ROM in grey*

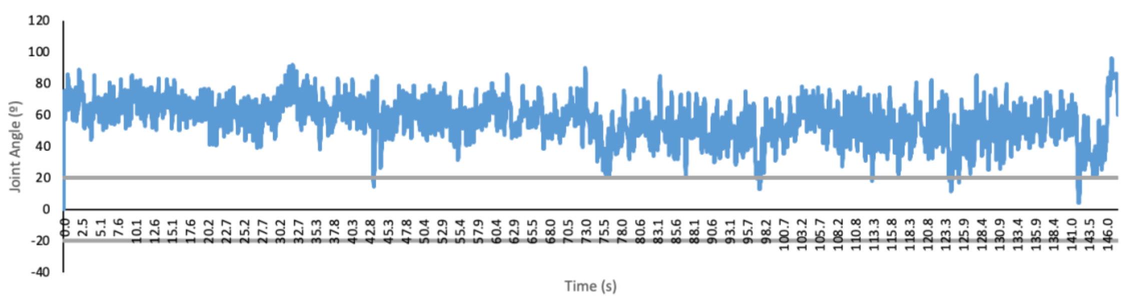



*Figure F.2.16 C02-17Right wrist pronation time series with neutral ROM in grey*

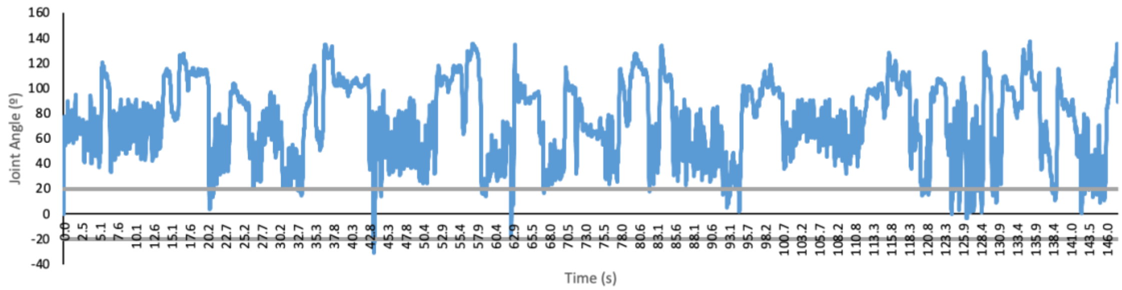



*Figure F.2.17 C02-17 Left wrist pronation time series with neutral ROM in grey*

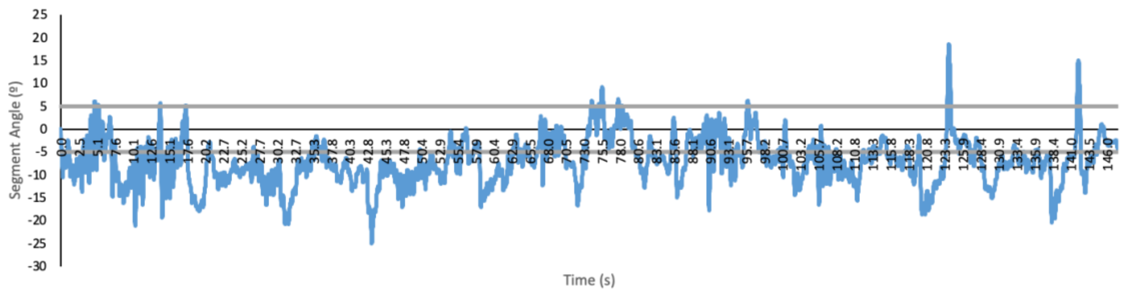



*Figure F.2.18 C02-17 Trunk flexion time series with neutral ROM in grey*

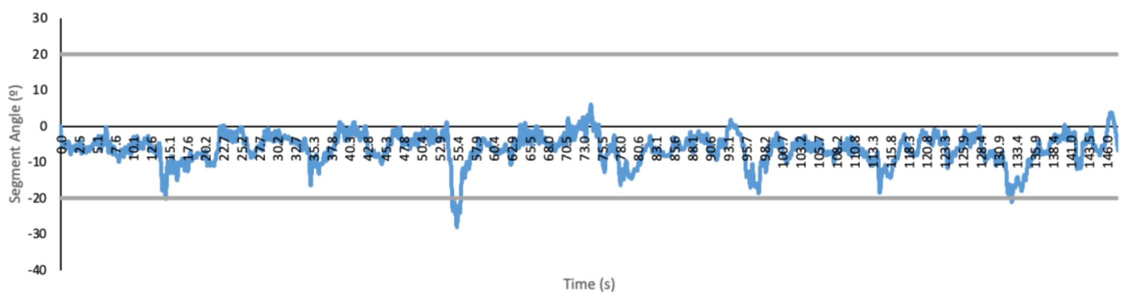



*Figure F.2.19 C02-17 Trunk lateral bending time series with neutral ROM in grey*

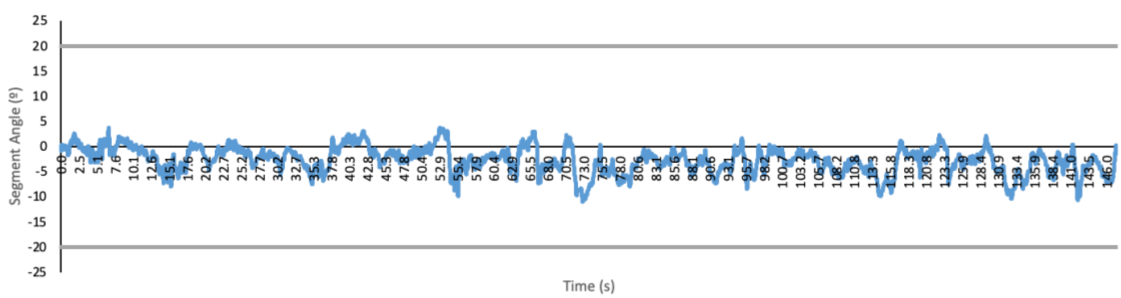



*Figure F.2.20 C02-17 Trunk axial rotation time series with neutral ROM in grey*

## Appendix F.3: Conductor 3

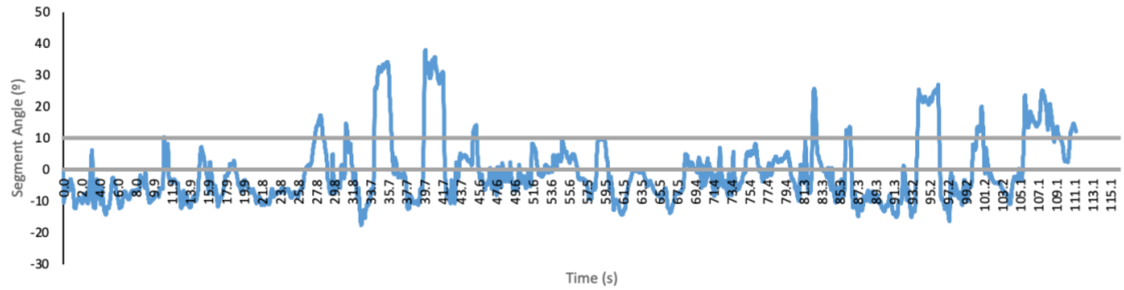



*Figure F.3.1 C03-14 Neck flexion time series with neutral ROM in grey*

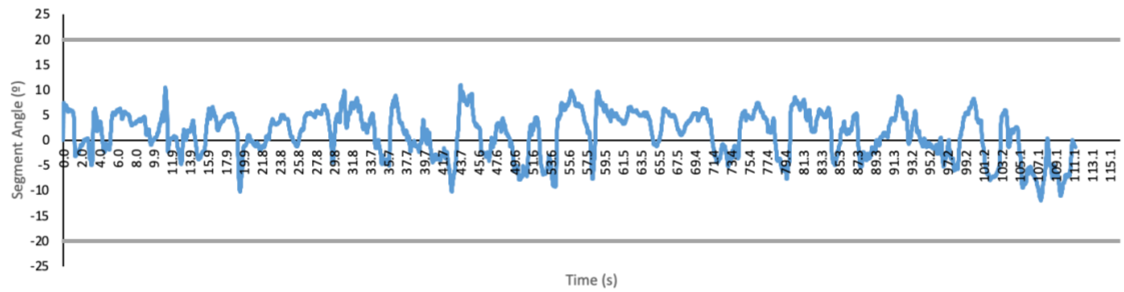



*Figure F.3.2 C03-14 Neck lateral bending time series with neutral ROM in grey*

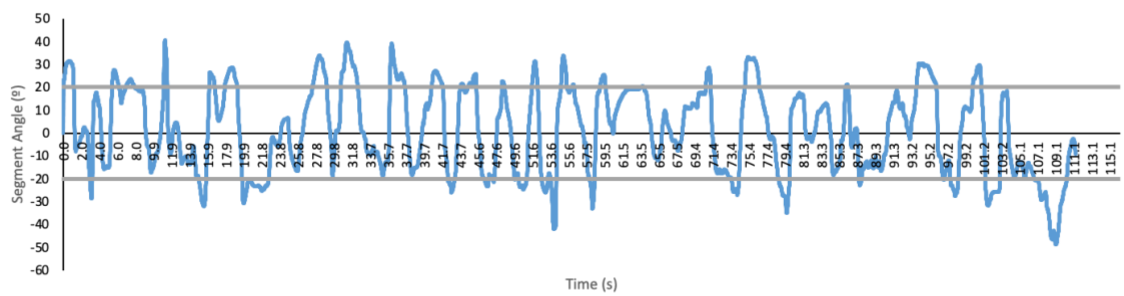



*Figure F.3.3 C03-14 Neck axial rotation time series with neutral ROM in grey*

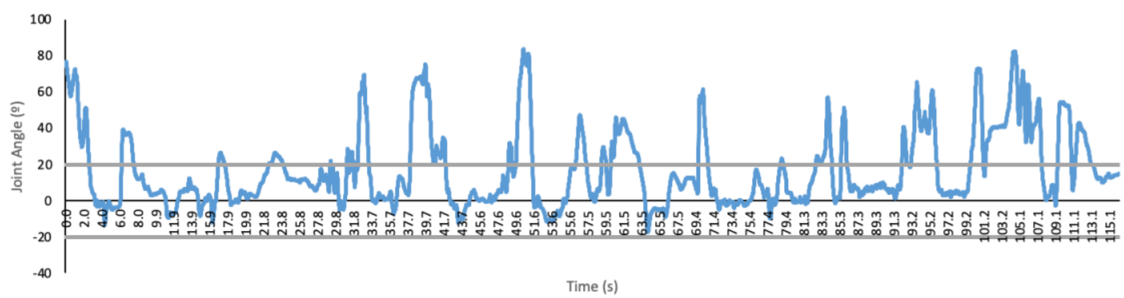



*Figure F.3.4 C03-14 Right shoulder flexion time series with neutral ROM in grey*

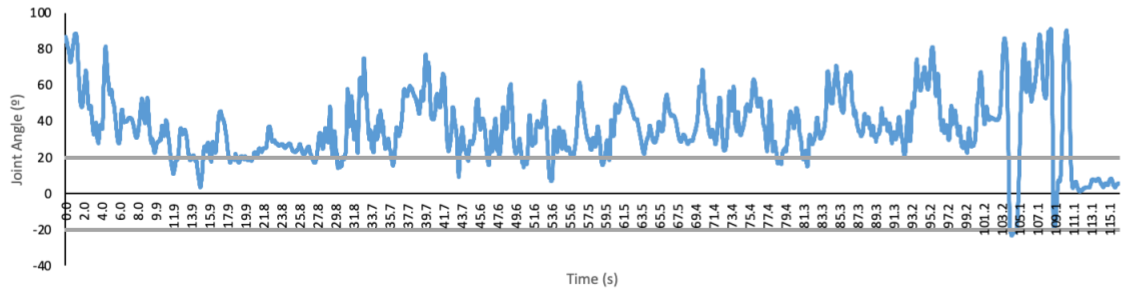



*Figure F.3.5 C03-14 Left shoulder flexion time series with neutral ROM in grey*

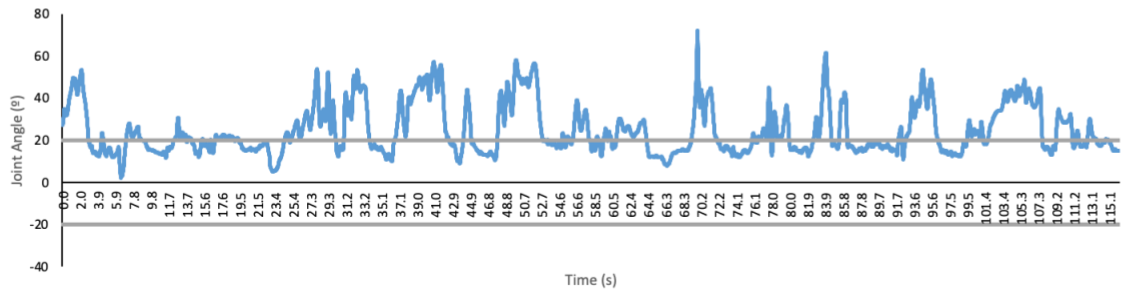



*Figure F.3.6 C03-14 Right shoulder abduction time series with neutral ROM in grey*

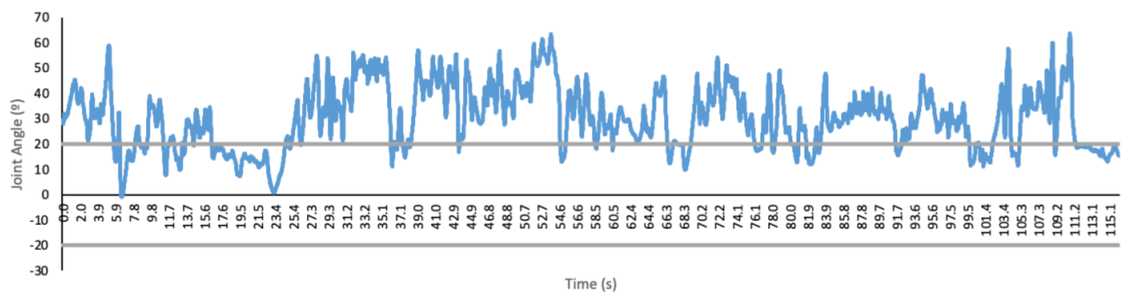



*Figure F.3.7 C03-14 Left shoulder abduction time series with neutral ROM in grey*

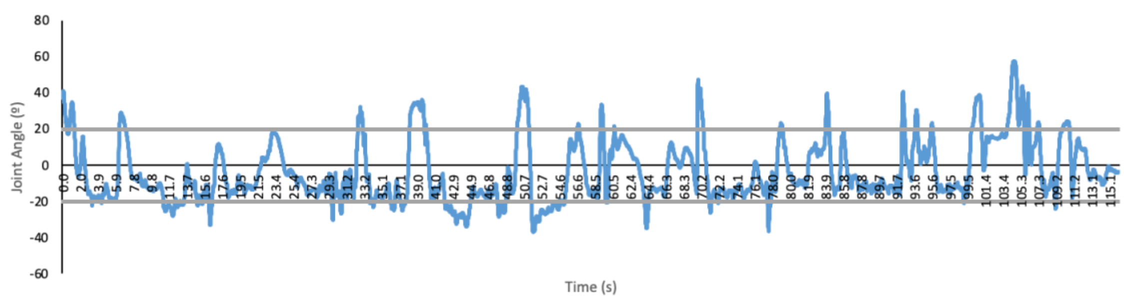



*Figure F.3.8 C03-14 Right shoulder rotation time series with neutral ROM in grey*

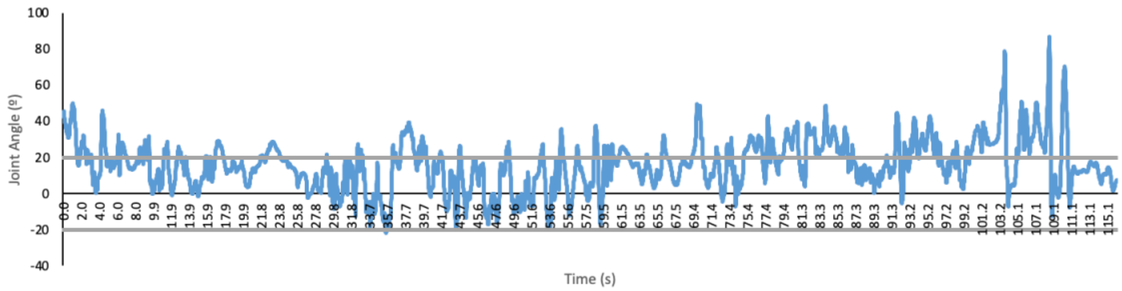



*Figure F.3.9 C03-14 Left shoulder rotation time series with neutral ROM in grey*

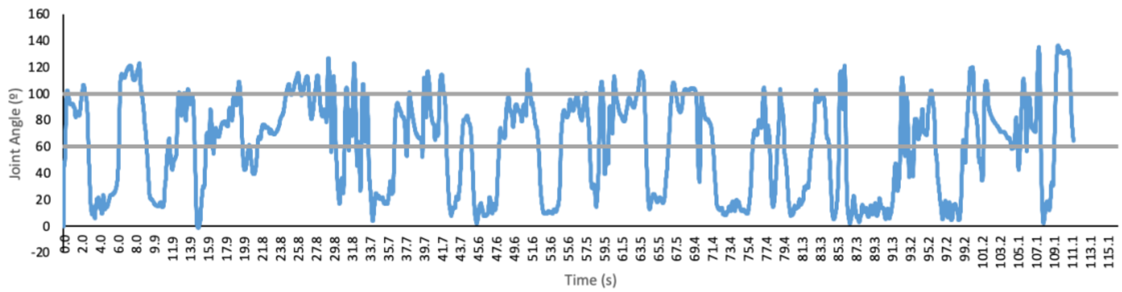



*Figure F.3.10 C03-14 Right elbow flexion time series with neutral ROM in grey*

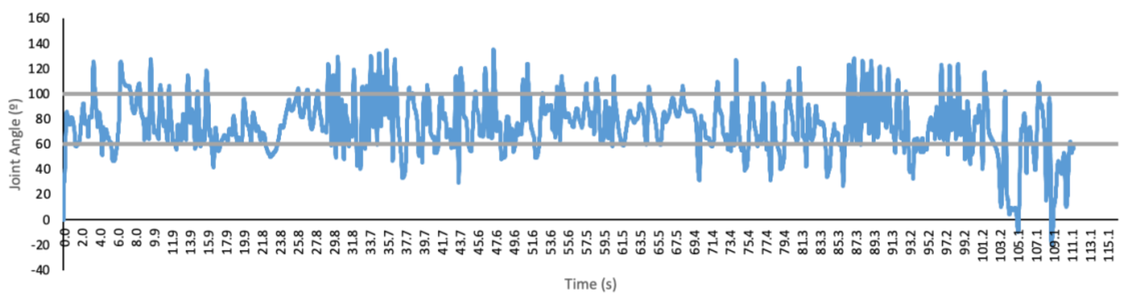



*Figure F.3.11 C03-14 Left elbow flexion time series with neutral ROM in grey*

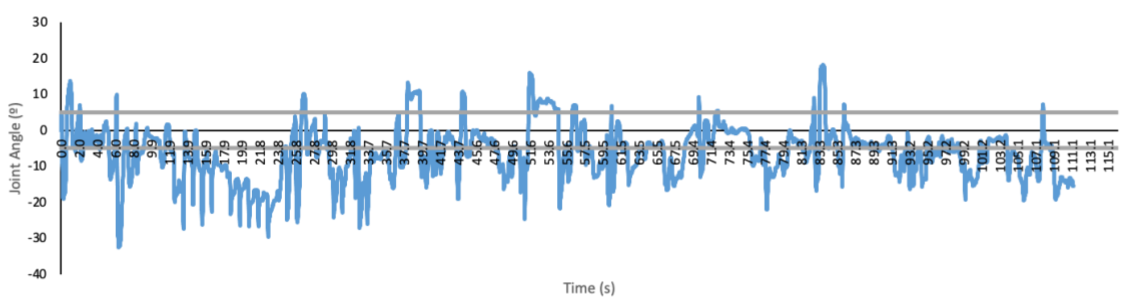



*Figure F.3.12 C03-14 Right wrist flexion time series with neutral ROM in grey*

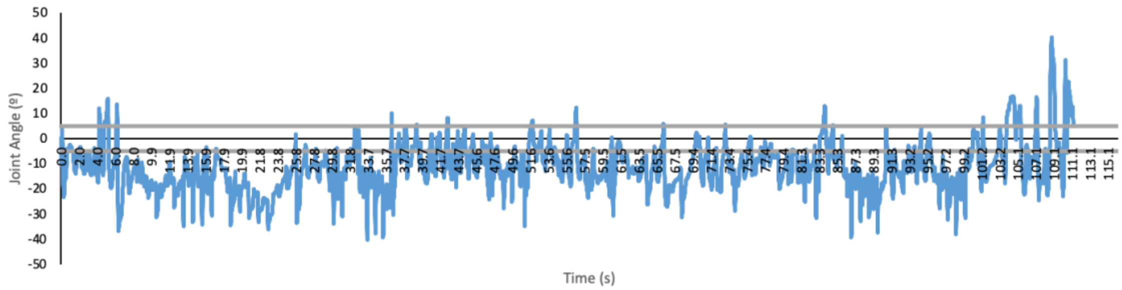



*Figure F.3.13 C03-14 Left wrist flexion time series with neutral ROM in grey*

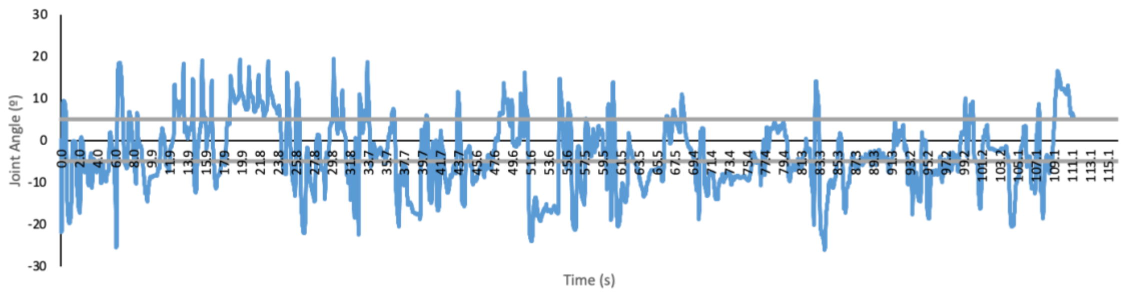



*Figure F.3.14 C03-14 Right wrist radial deviation time series with neutral ROM in grey*

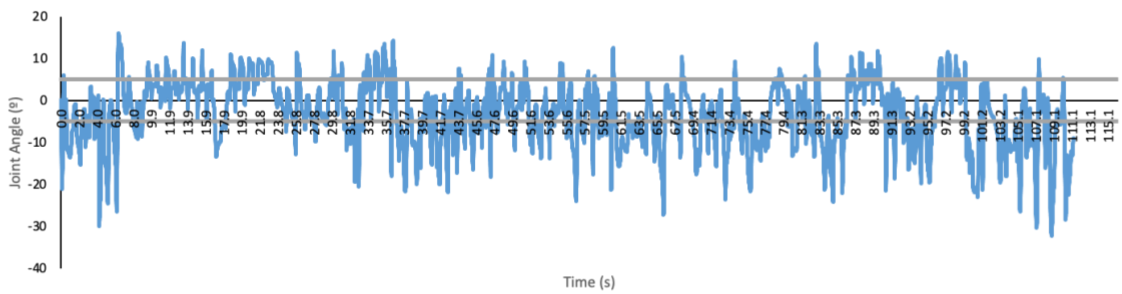



*Figure F.3.15 C03-14 Left wrist radial deviation time series with neutral ROM in grey*

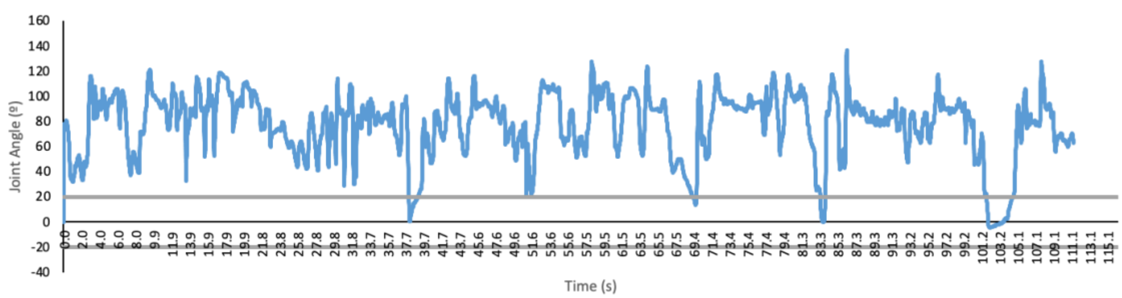



*Figure F.3.16 C03-14 Right wrist pronation time series with neutral ROM in grey*

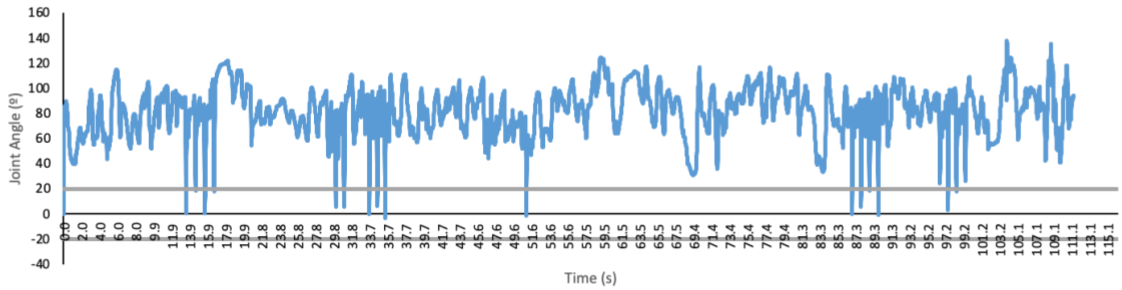



*Figure F.3.17 C03-14 Left wrist pronation time series with neutral ROM in grey*

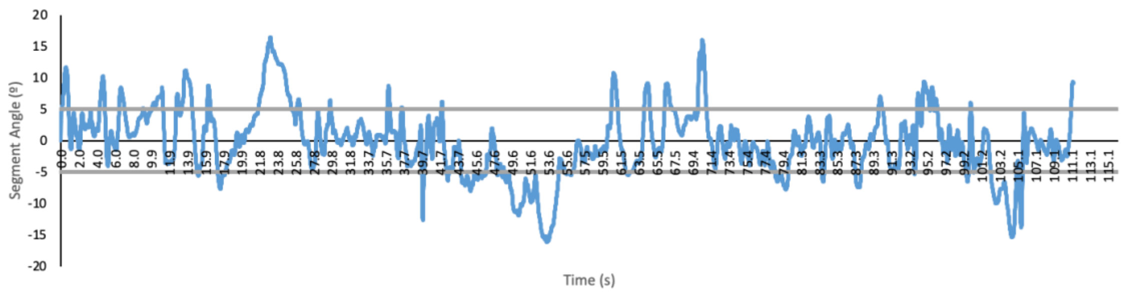



*Figure F.3.18 C03-14 Trunk flexion time series with neutral ROM in grey*

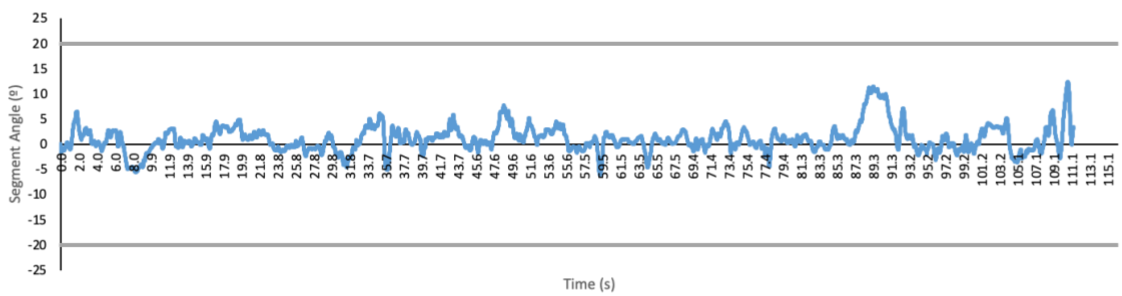



*Figure F.3.19 C03-14 Trunk lateral bending time series with neutral ROM in grey*

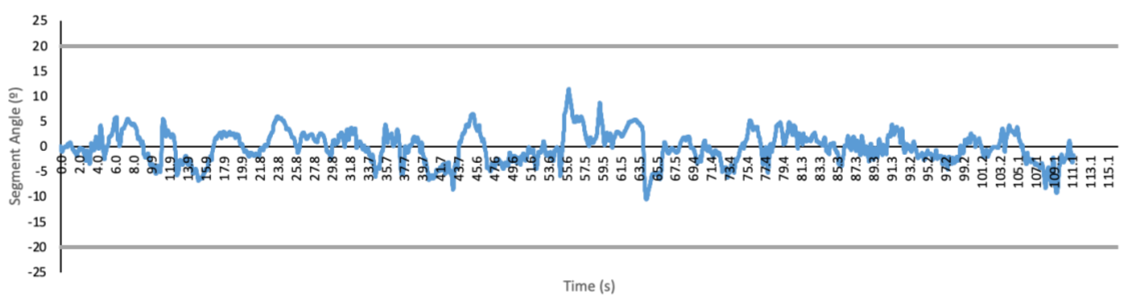



*Figure F.3.20 C03-14 Trunk axial rotation time series with neutral ROM in grey*

## Appendix F.4: Conductor 4

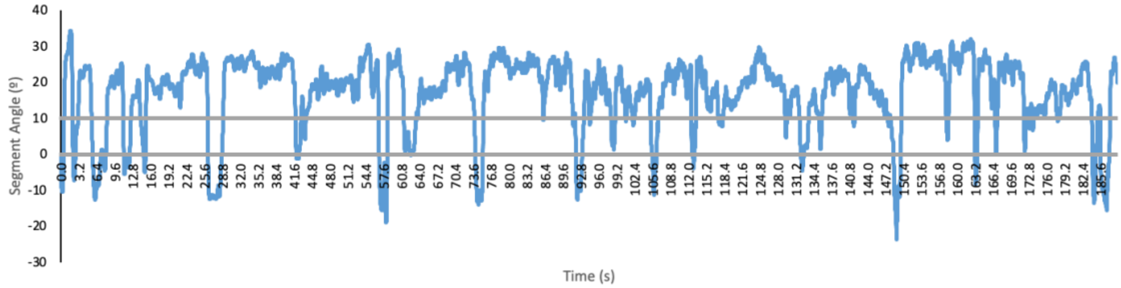



*Figure F.4.1: C04-4 Neck flexion time series with neutral ROM in grey*

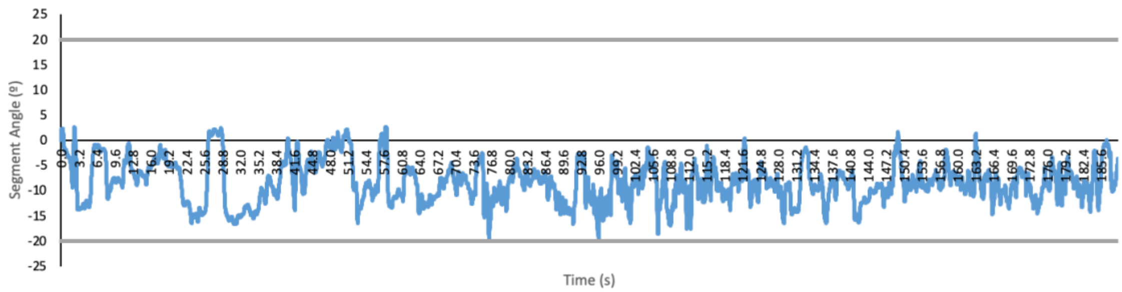



*Figure F.4.2 C04-4 Neck lateral bending time series with neutral ROM in grey*

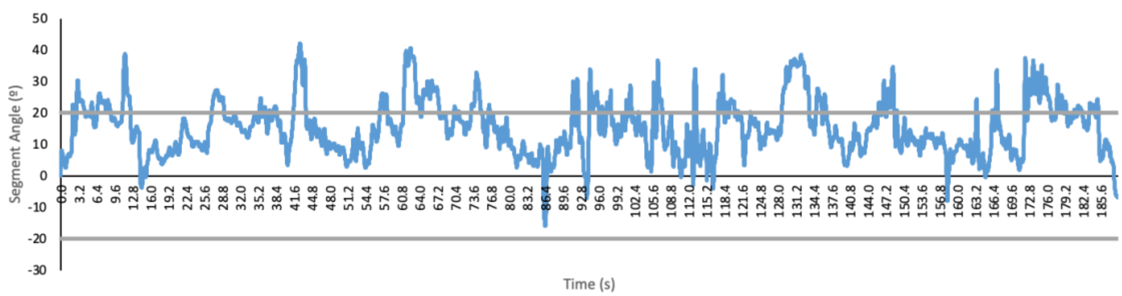



*Figure F.4.3 C04-4 Neck axial rotation time series with neutral ROM in grey*

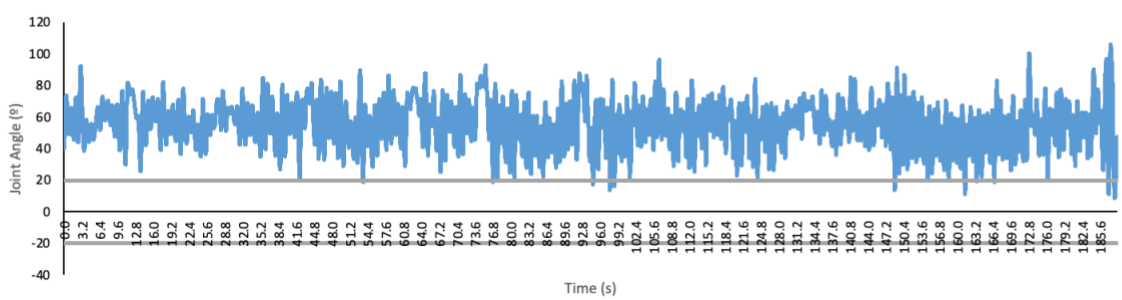



*Figure F.4.4 C04-4 Right shoulder flexion time series with neutral ROM in grey*

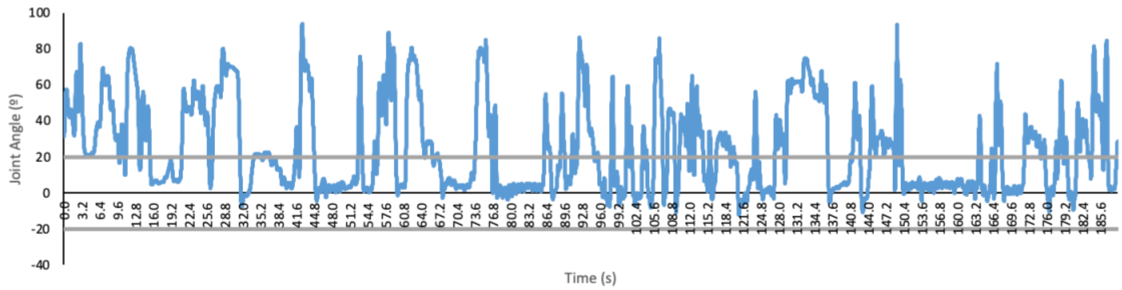



*Figure F.4.5 C04-4 Left shoulder flexion time series with neutral ROM in grey*

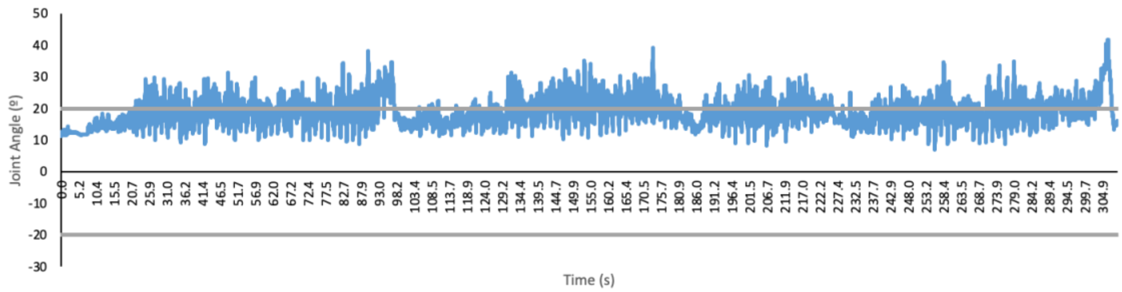



*Figure F.4.6 C04-4 Right shoulder abduction time series with neutral ROM in grey*

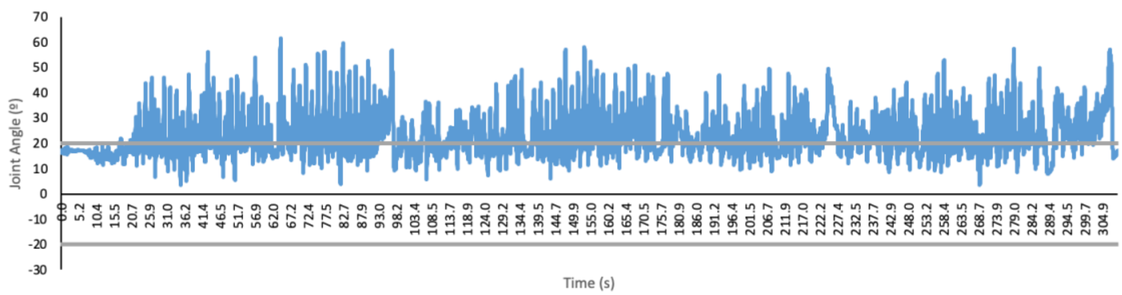



*Figure F.4.7 C04-4 Left shoulder abduction time series with neutral ROM in grey*

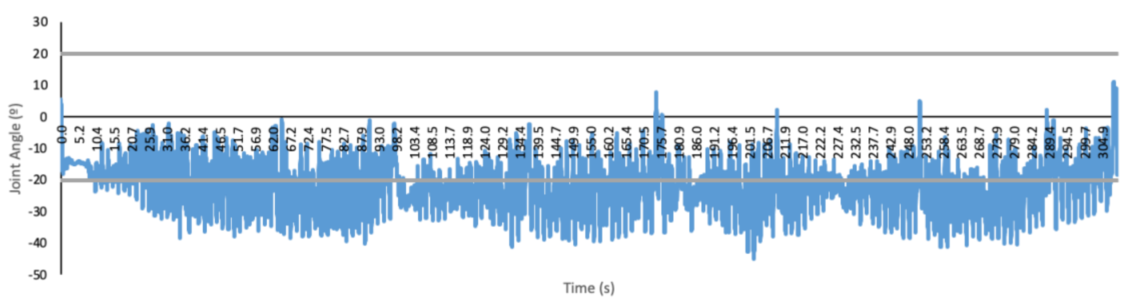



*Figure F.4.8 C04-4 Right shoulder rotation time series with neutral ROM in grey*

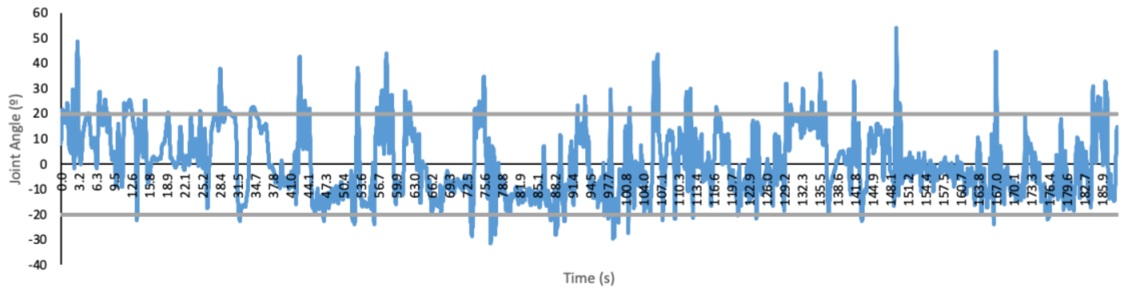



*Figure F.4.9 C04-4 Left shoulder rotation time series with neutral ROM in grey*

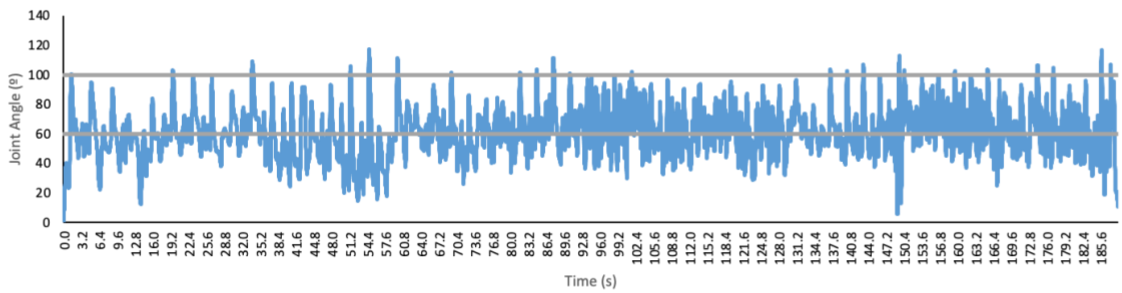



*Figure F.4.10 C04-4 Right elbow flexion time series with neutral ROM in grey*

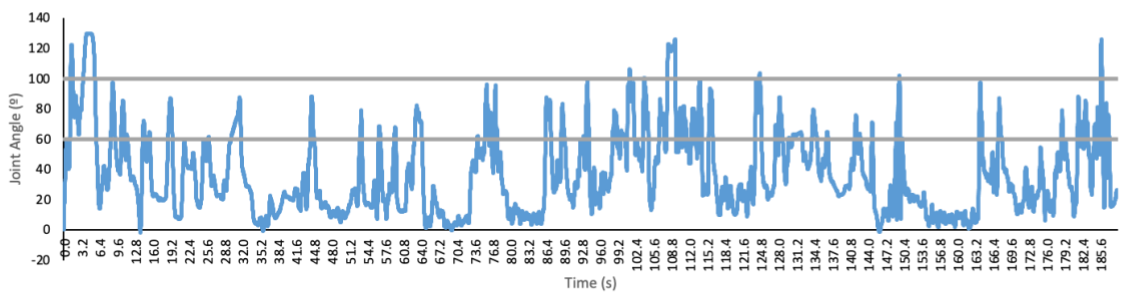



*Figure F.4.11 C04-4 Left elbow flexion time series with neutral ROM in grey*

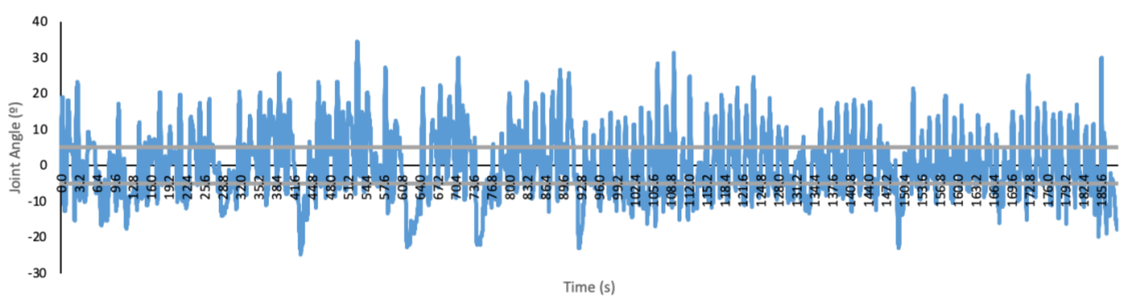



*Figure F.4.12 C04-4 Right wrist flexion time series with neutral ROM in grey*

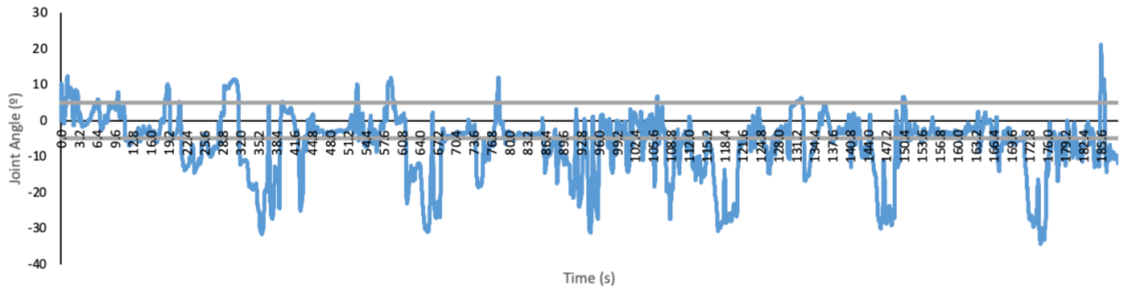



*Figure F.4.13 C04-4 Left wrist flexion time series with neutral ROM in grey*

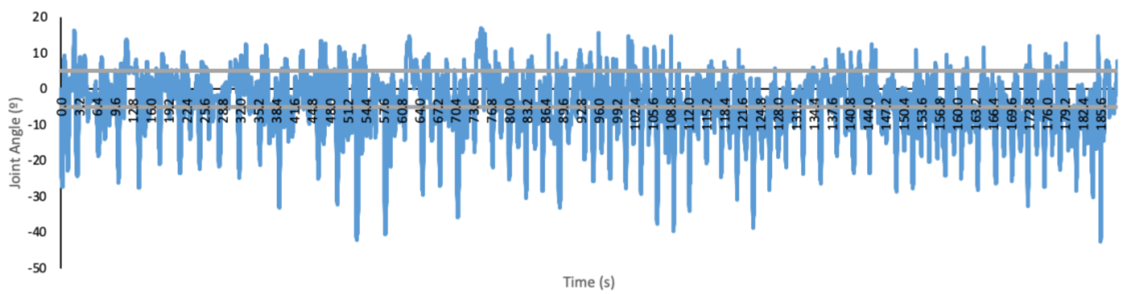



*Figure F.4.14 C04-4 Right wrist radial deviation time series with neutral ROM in grey*

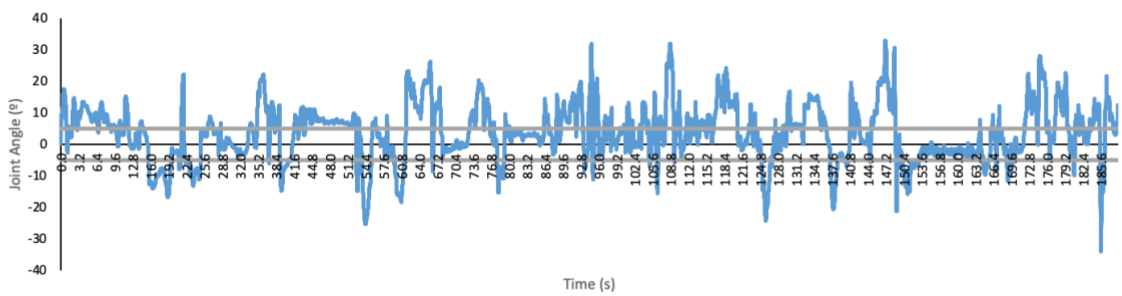



*Figure F.4.15 C04-4 Left wrist radial deviation time series with neutral ROM in grey*

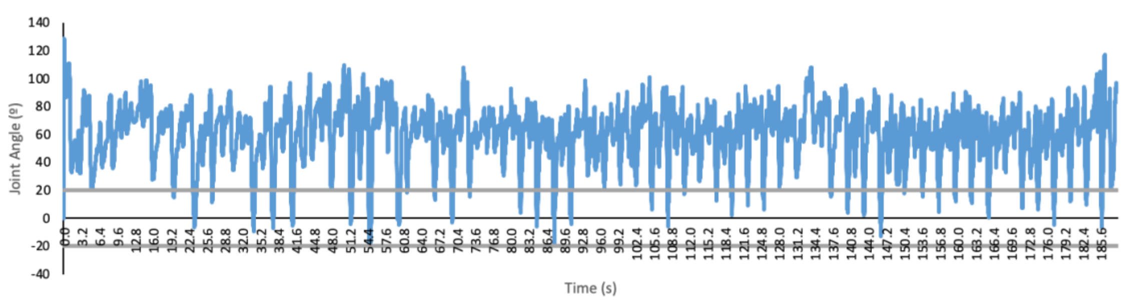



*Figure F.4.16 C04-4 Right wrist pronation time series with neutral ROM in grey*

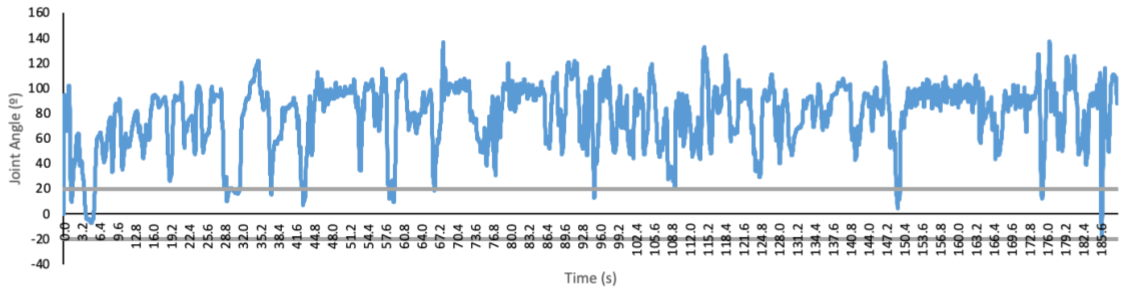



*Figure F.4.17 C04-4 Left wrist pronation time series with neutral ROM in grey*

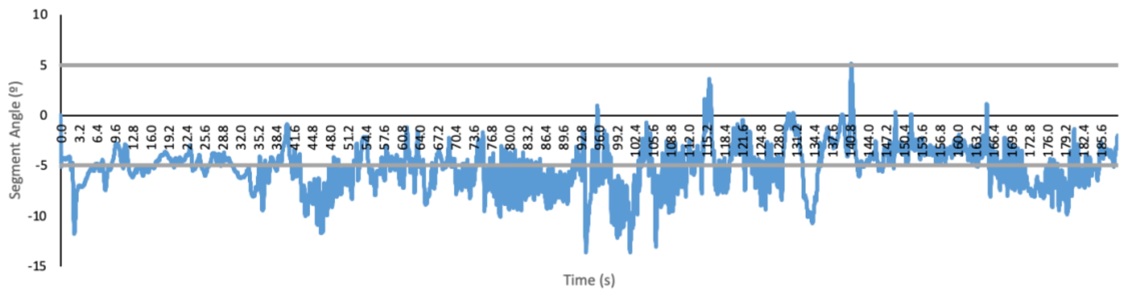



*Figure F.4.18 C04-4 Trunk flexion time series with neutral ROM in grey*

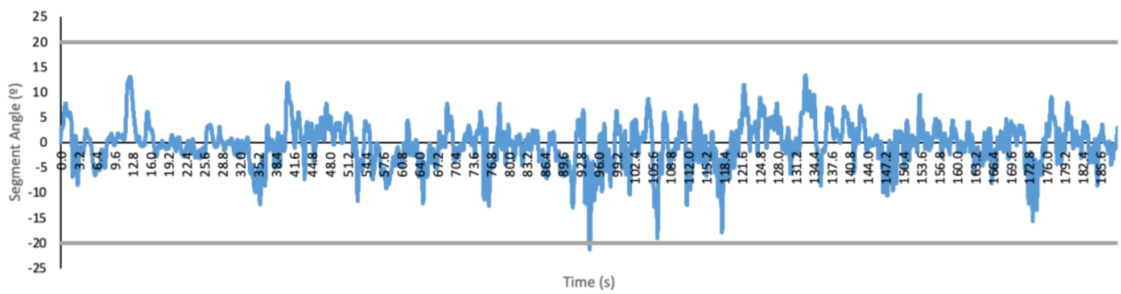



*Figure F.4.19 C04-4 Trunk lateral bending time series with neutral ROM in grey*

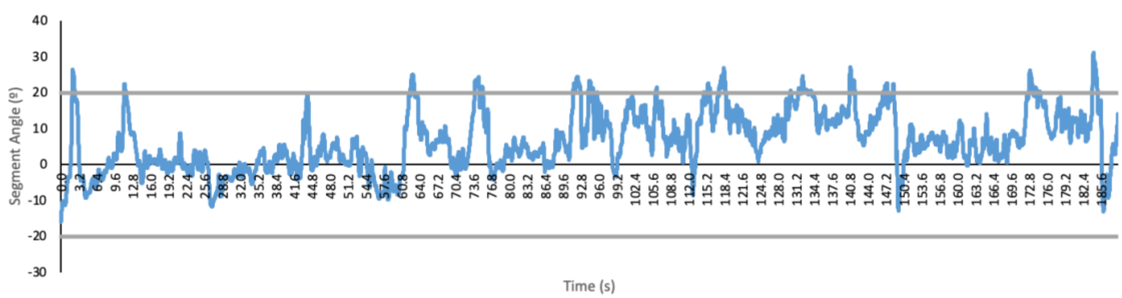



*Figure F.4.20 C04-4 Trunk axial rotation time series with neutral ROM in grey*

# Appendix F.5: Conductor 5

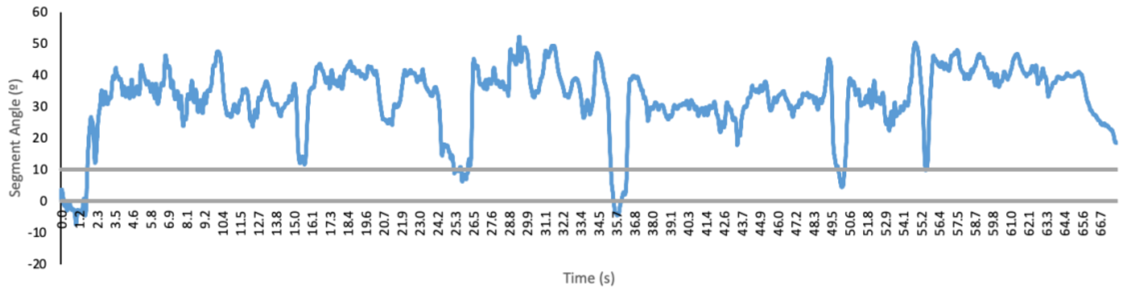



*Figure F.5.1: C05-08 Neck flexion time series with neutral ROM in grey*

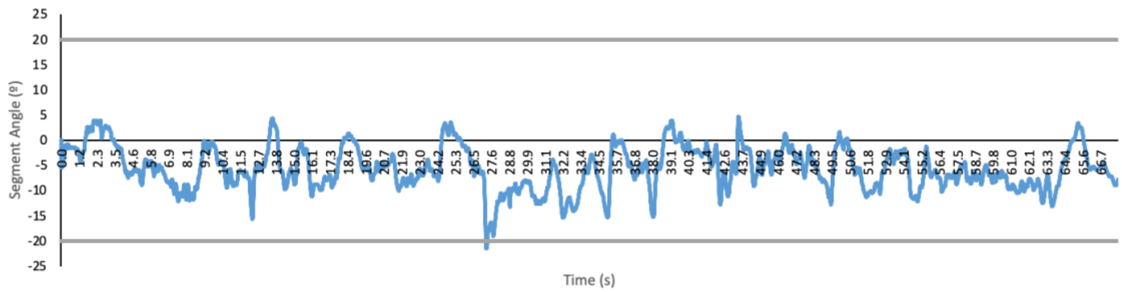



*Figure F.5.2 C05-08 Neck lateral bending time series with neutral ROM in grey*

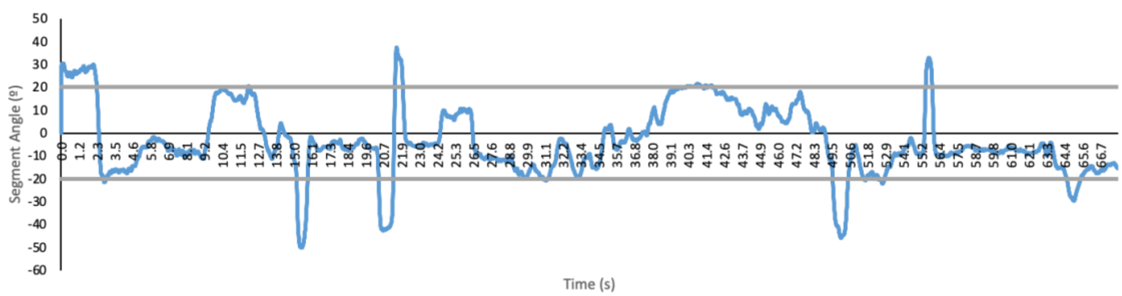



*Figure F.5.3 C05-08 Neck axial rotation time series with neutral ROM in grey*

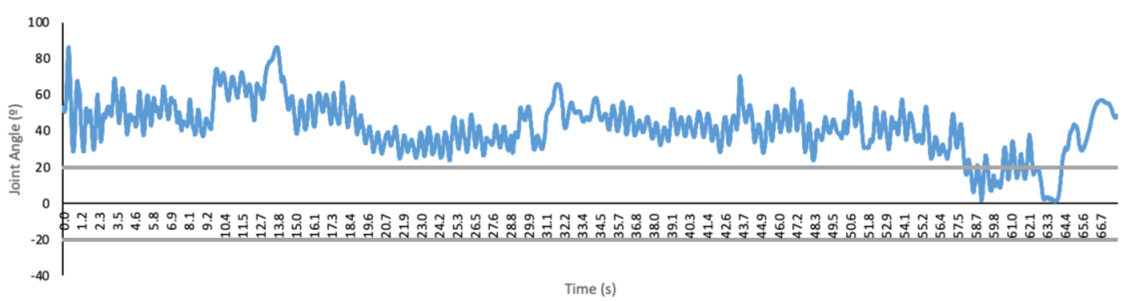



*Figure F.5.4 C05-08 Right shoulder flexion time series with neutral ROM in grey*

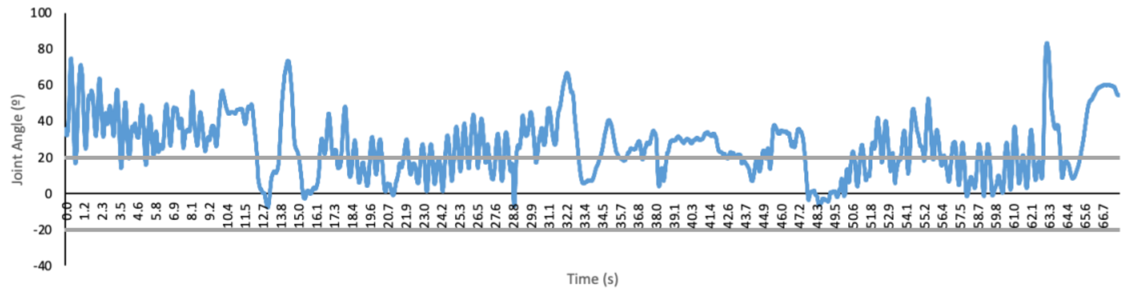



*Figure F.5.5 C05-08 Left shoulder flexion time series with neutral ROM in grey*

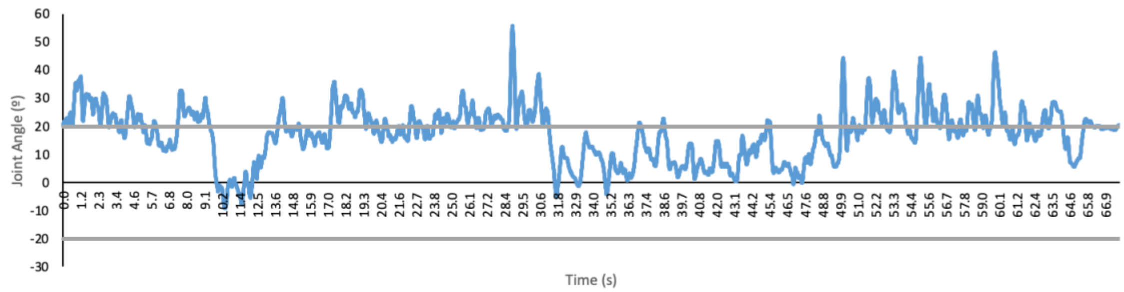



*Figure F.5.6 C05-08 Right shoulder abduction time series with neutral ROM in grey*

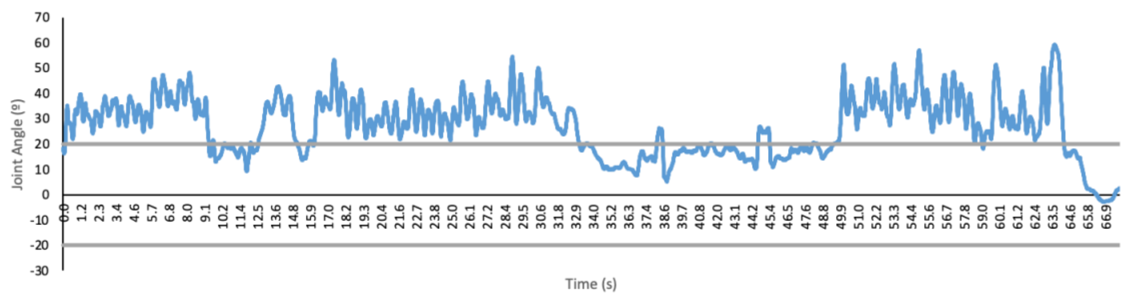



*Figure F.5.7 C05-08 Left shoulder abduction time series with neutral ROM in grey*

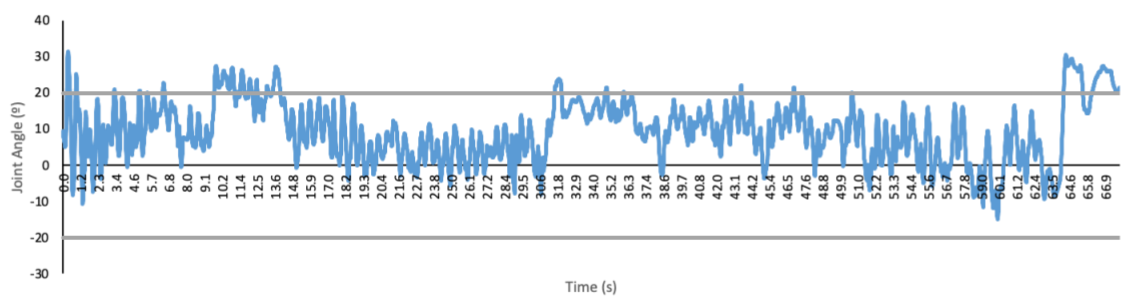



*Figure F.5.8 C05-08 Right shoulder rotation time series with neutral ROM in grey*

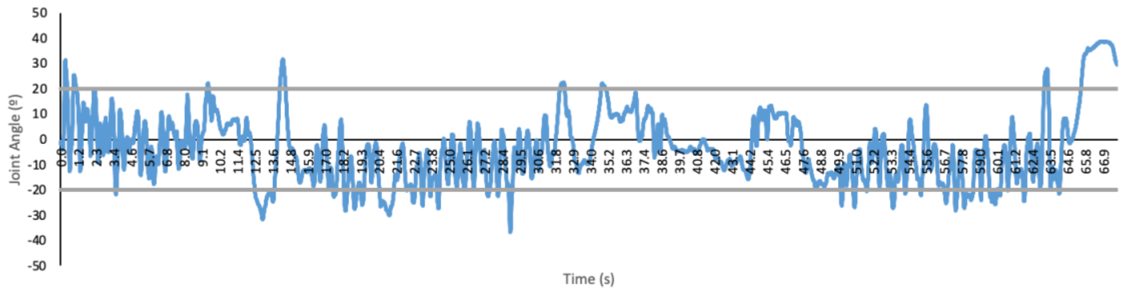



*Figure F.5.9 C05-08 Left shoulder rotation time series with neutral ROM in grey*

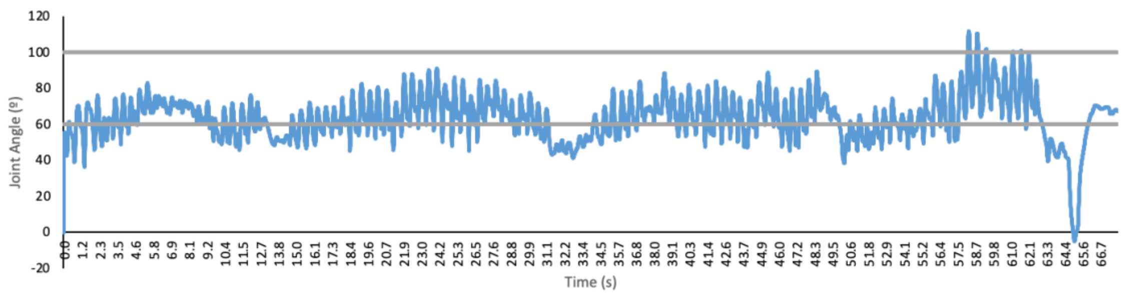



*Figure F.5.10 C05-08 Right elbow flexion time series with neutral ROM in grey*

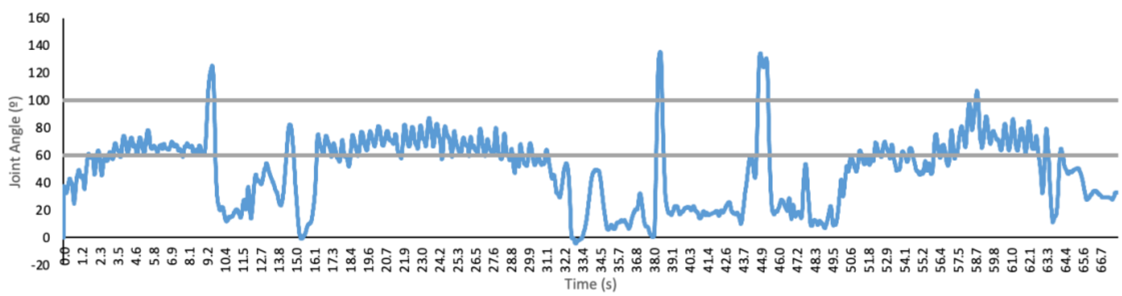



*Figure F.5.11 C05-08 Left elbow flexion time series with neutral ROM in grey*

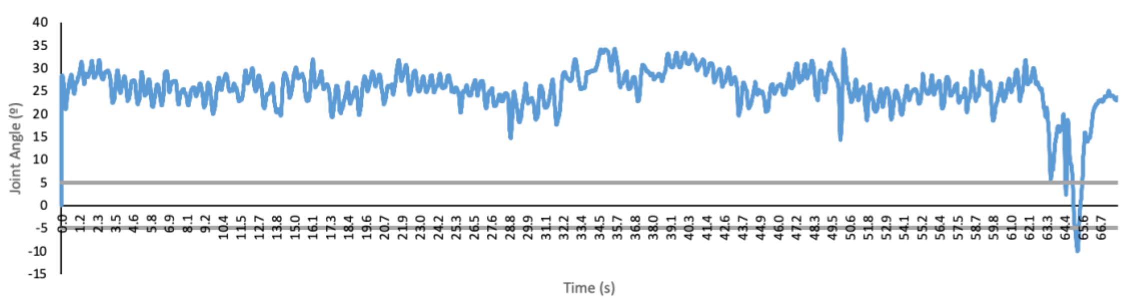



*Figure F.5.12 C05-08 Right wrist flexion time series with neutral ROM in grey*

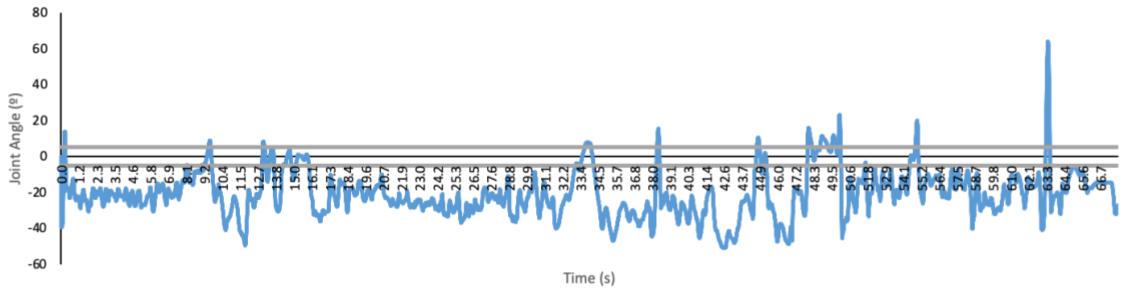



*Figure F.5.13 C05-08 Left wrist flexion time series with neutral ROM in grey*

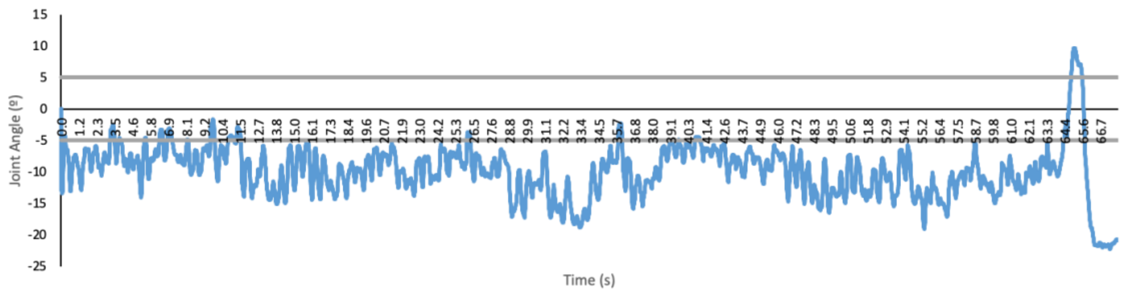



*Figure F.5.14 C05-08 Right wrist radial deviation time series with neutral ROM in grey*

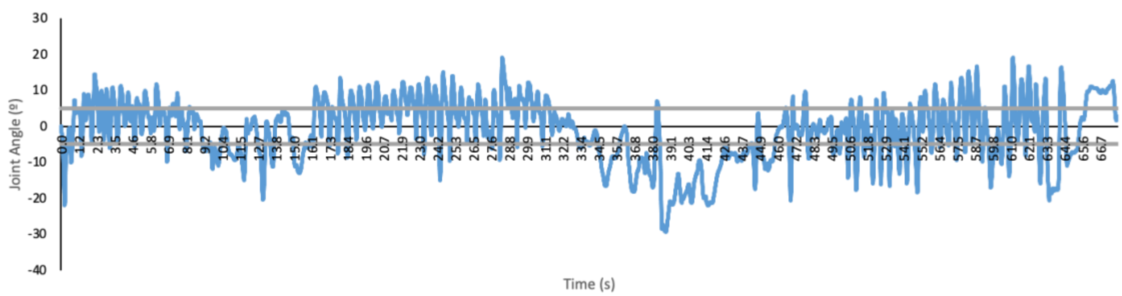



*Figure F.5.15 C05-08 Left wrist radial deviation time series with neutral ROM in grey*

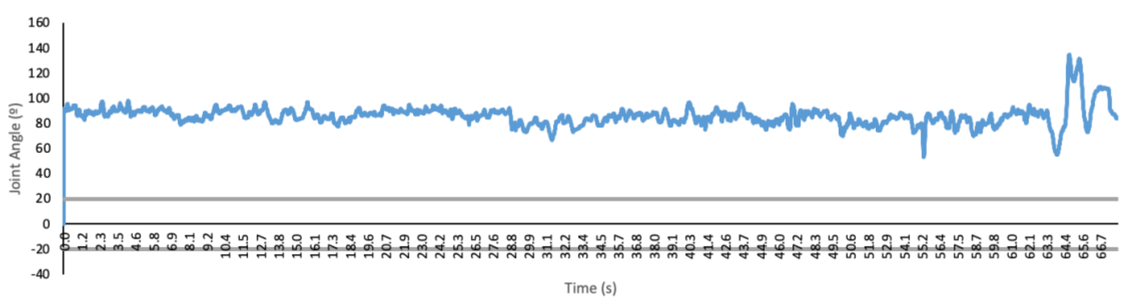



*Figure F.5.16 C05-08 Right wrist pronation time series with neutral ROM in grey*

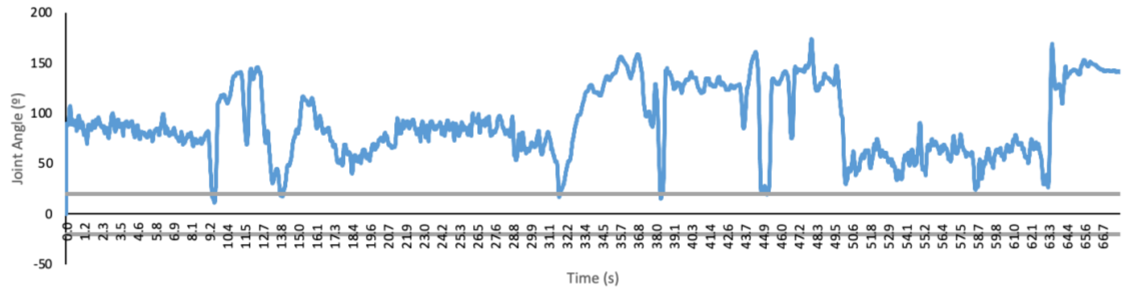



*Figure F.5.17 C05-08 Left wrist pronation time series with neutral ROM in grey*

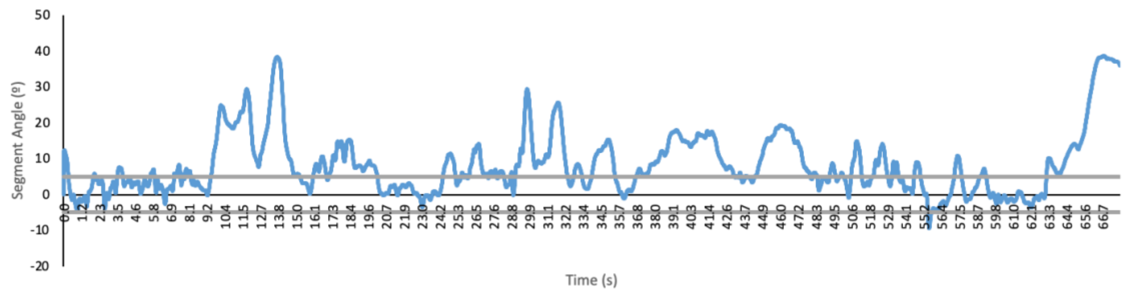



*Figure F.5.18 C05-08 Trunk flexion time series with neutral ROM in grey*

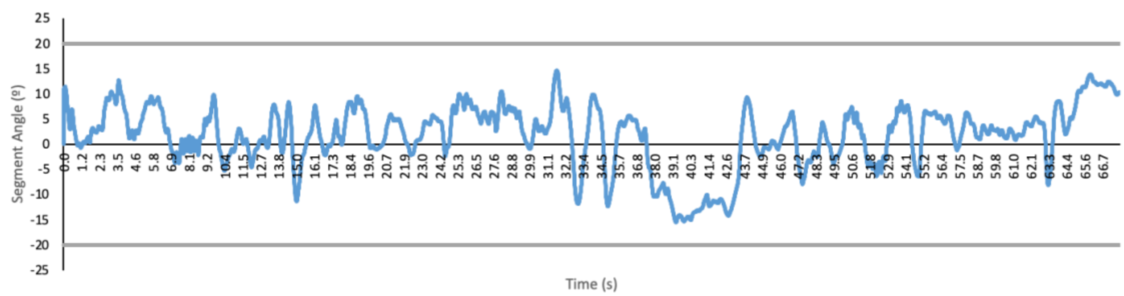



*Figure F.5.19 C05-08 Trunk lateral bending time series with neutral ROM in grey*

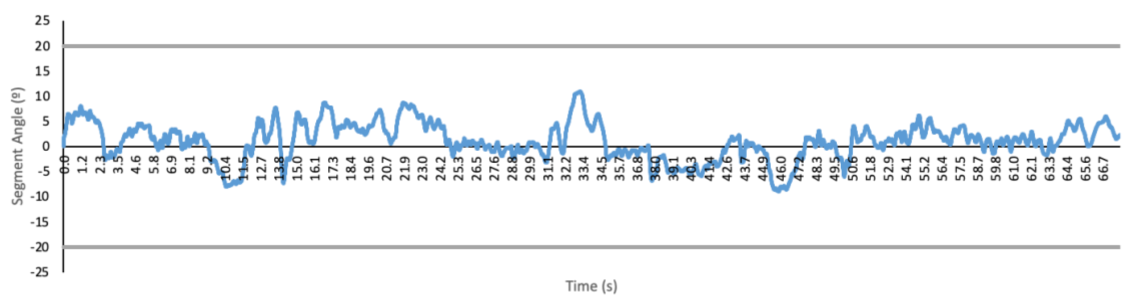



*Figure F.5.20 C05-08 Trunk axial rotation time series with neutral ROM in grey*

# Appendix F.6: Conductor 6

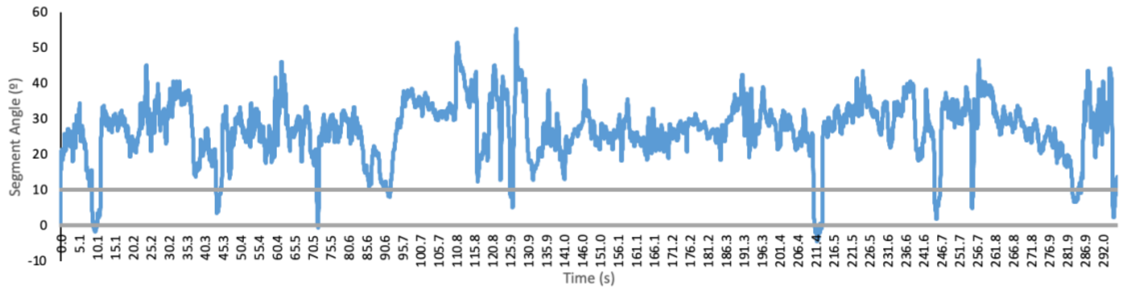



*Figure F.6.1: C06-19 Neck flexion time series with neutral ROM in grey*

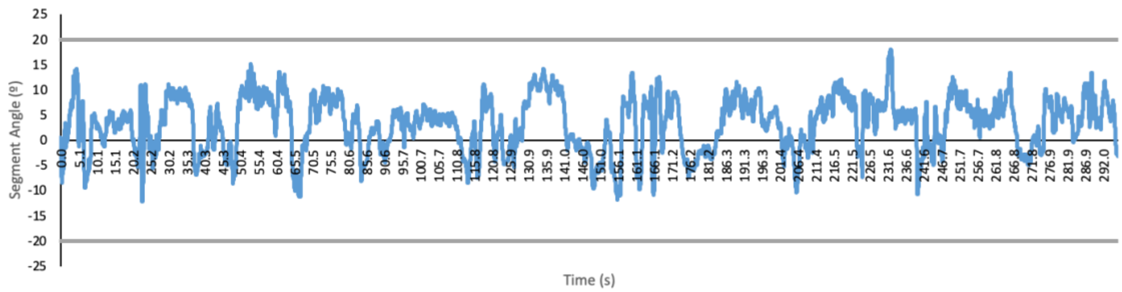



*Figure F.6.2 C06-19 Neck lateral bending time series with neutral ROM in grey*

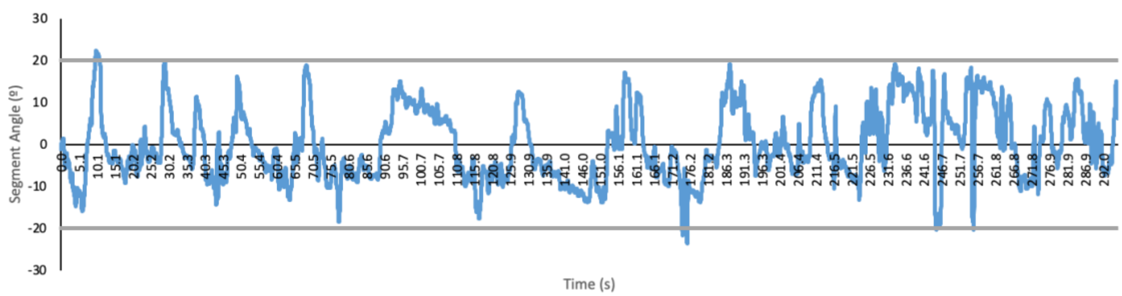



*Figure F.6.3 C06-19 Neck axial rotation time series with neutral ROM in grey*

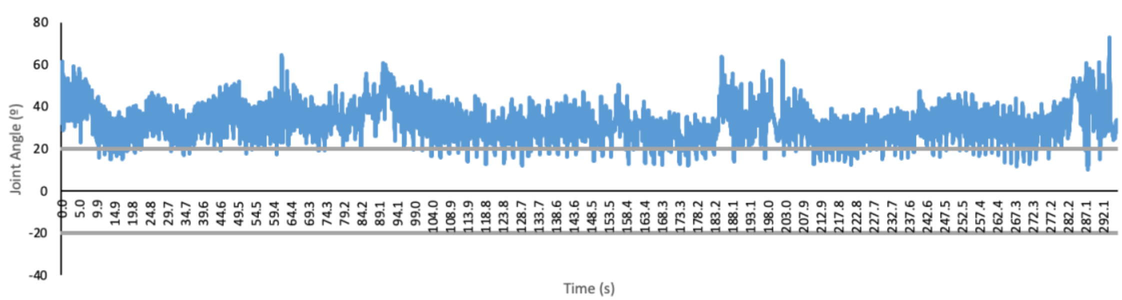



*Figure F.6.4 C06-19 Right shoulder flexion time series with neutral ROM in grey*

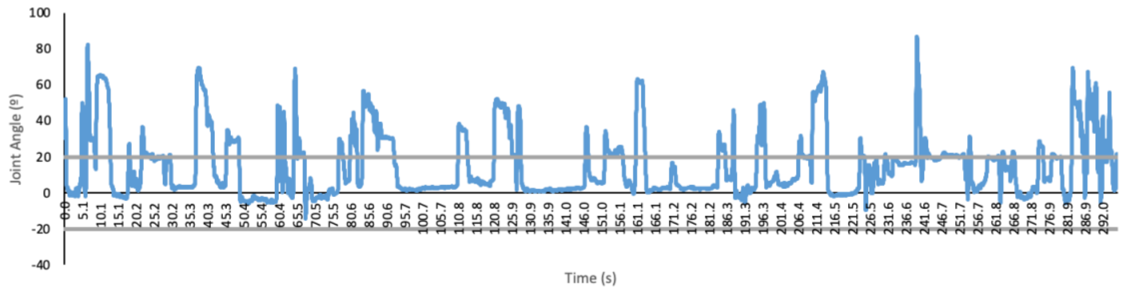



*Figure F.6.5 C06-19 Left shoulder flexion time series with neutral ROM in grey*

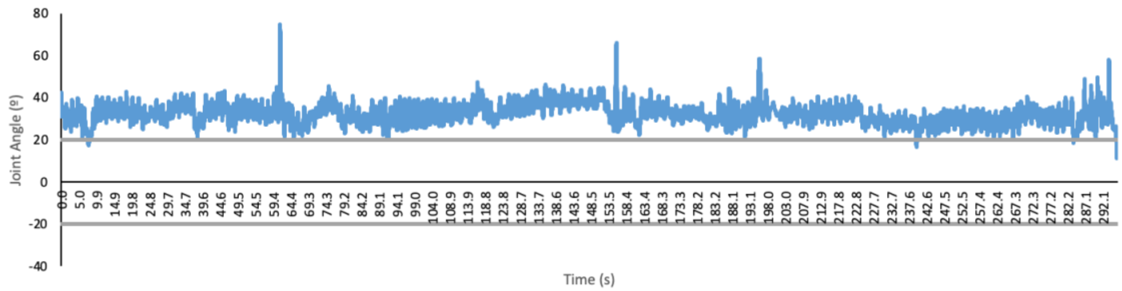



*Figure F.6.6 C06-19 Right shoulder abduction time series with neutral ROM in grey*

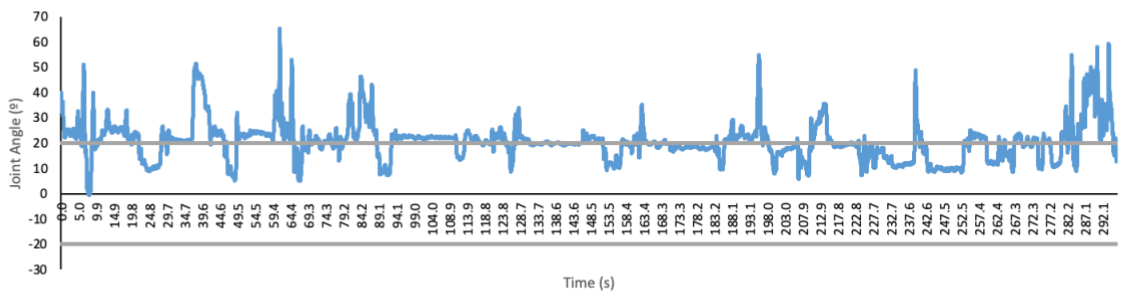



*Figure F.6.7 C06-19 Left shoulder abduction time series with neutral ROM in grey*

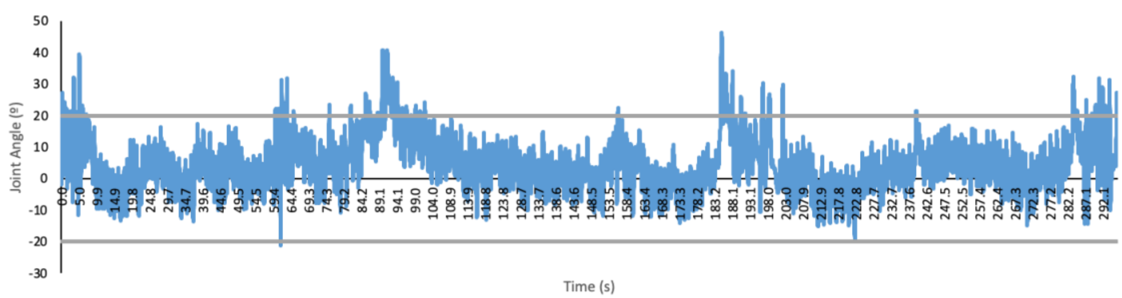



*Figure F.6.8 C06-19 Right shoulder rotation time series with neutral ROM in grey*

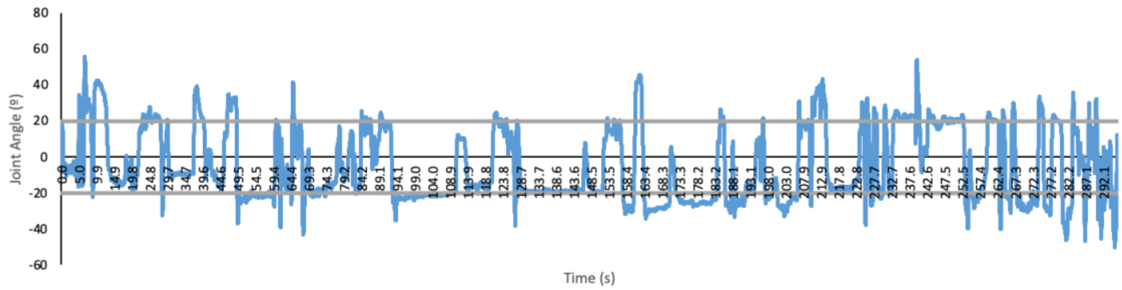



*Figure F.6.9 C06-19 Left shoulder rotation time series with neutral ROM in grey*

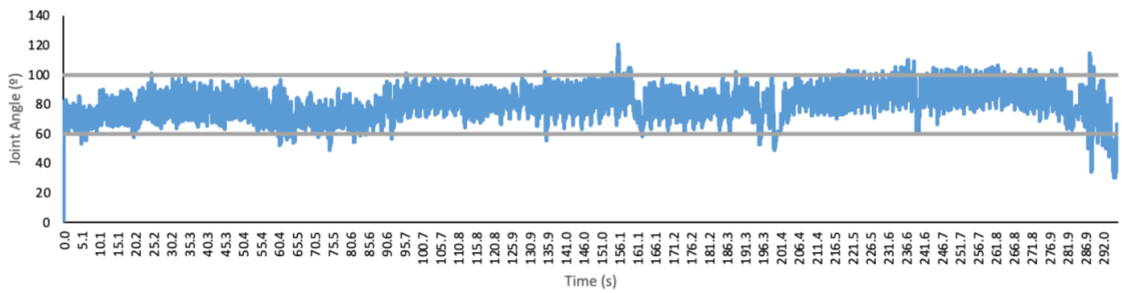



*Figure F.6.10 C06-19 Right elbow flexion time series with neutral ROM in grey*

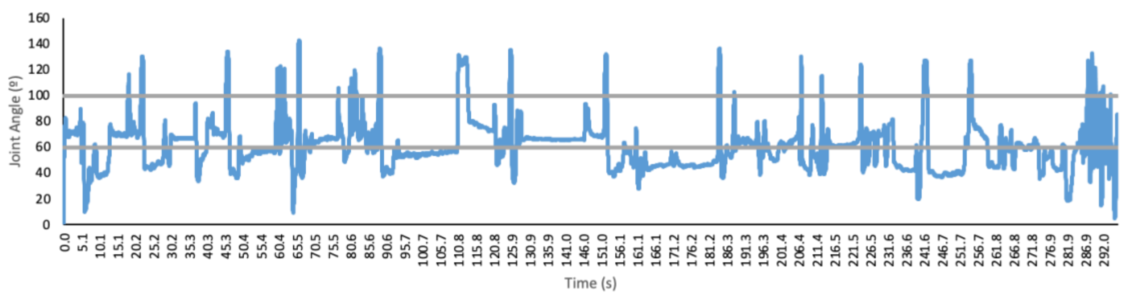



*Figure F.6.11 C06-19 Left elbow flexion time series with neutral ROM in grey*

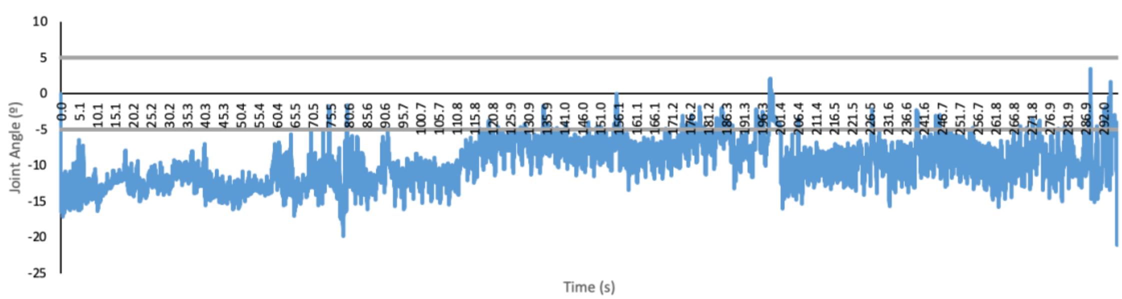



*Figure F.6.12 C06-19 Right wrist flexion time series with neutral ROM in grey*

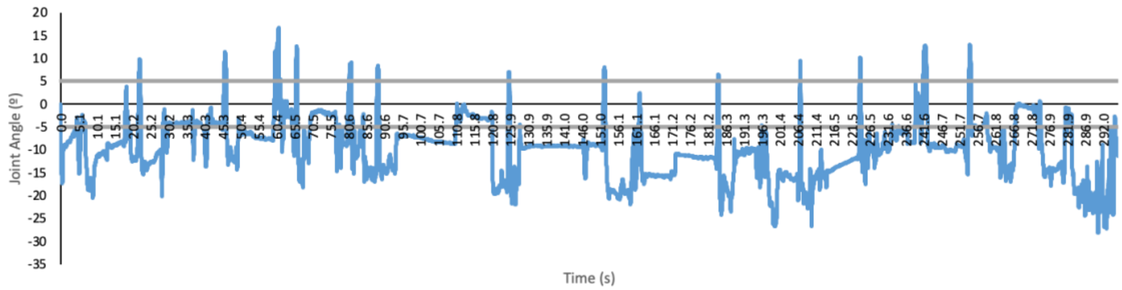



*Figure F.6.13 C06-19 Left wrist flexion time series with neutral ROM in grey*

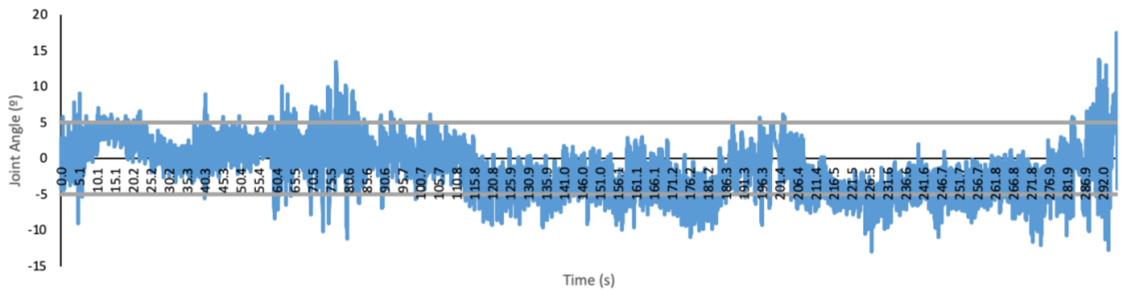



*Figure F.6.14 C06-19 Right wrist radial deviation time series with neutral ROM in grey*

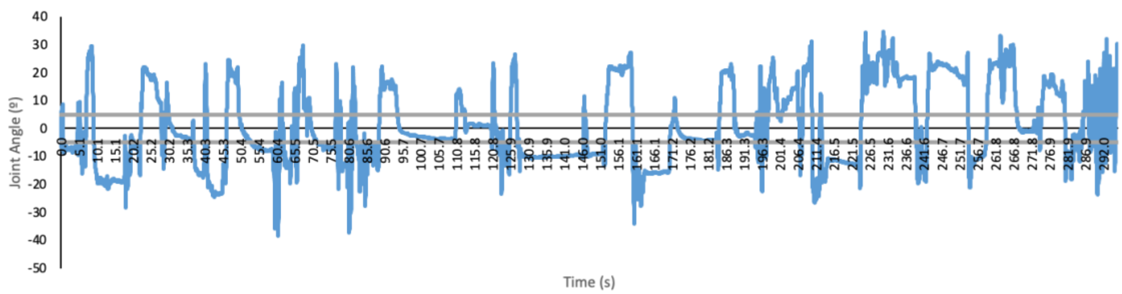



*Figure F.6.15 C06-19 Left wrist radial deviation time series with neutral ROM in grey*

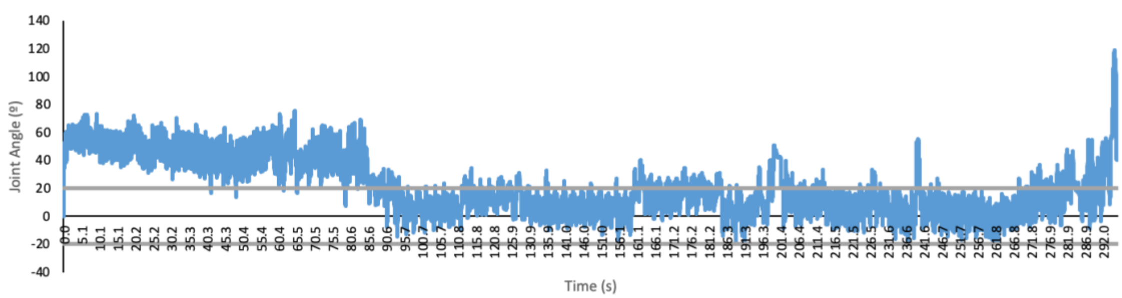



*Figure F.6.16 C06-19 Right wrist pronation time series with neutral ROM in grey*

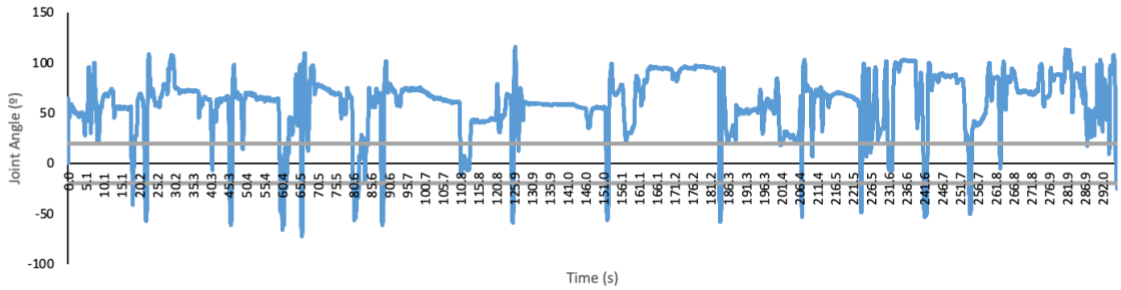



*Figure F.6.17 C06-19 Left wrist pronation time series with neutral ROM in grey*

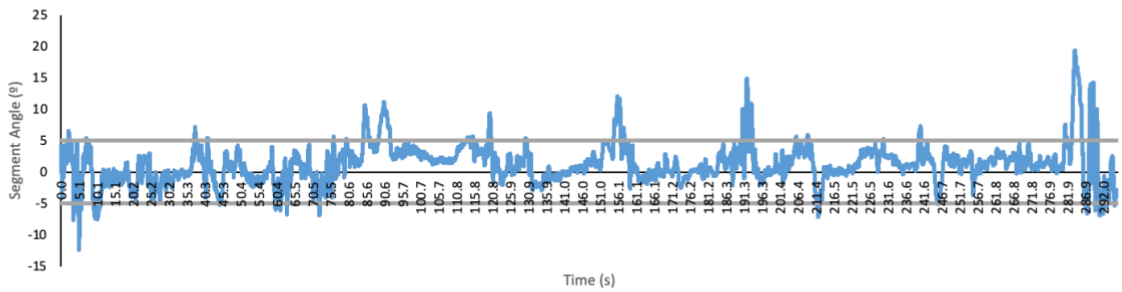



*Figure F.6.18 C06-19 Trunk flexion time series with neutral ROM in grey*

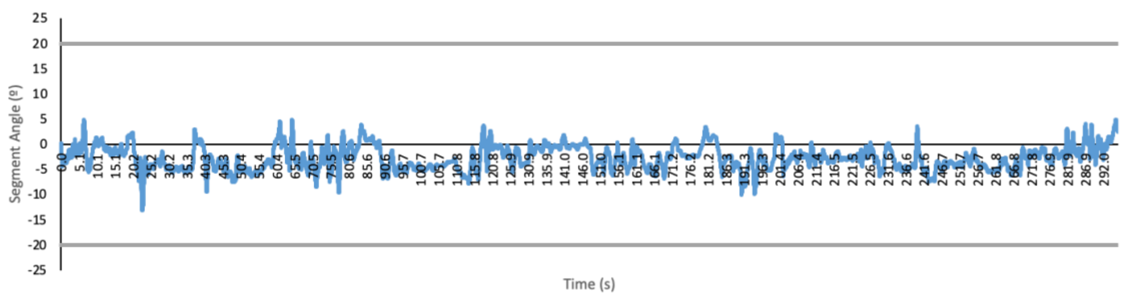



*Figure F.6.19 C06-19 Trunk lateral bending time series with neutral ROM in grey*

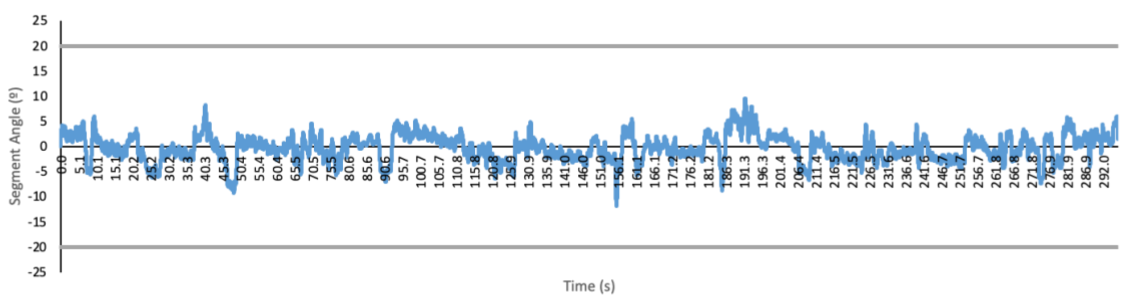



*Figure F.6.20 C06-19 Trunk axial rotation time series with neutral ROM in grey*

## Appendix F.7: Conductor 7

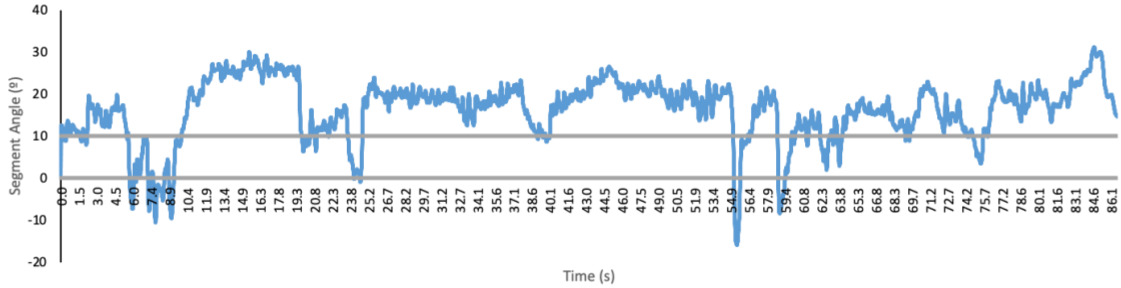



*Figure F.7.1: C07-13 Neck flexion time series with neutral ROM in grey*

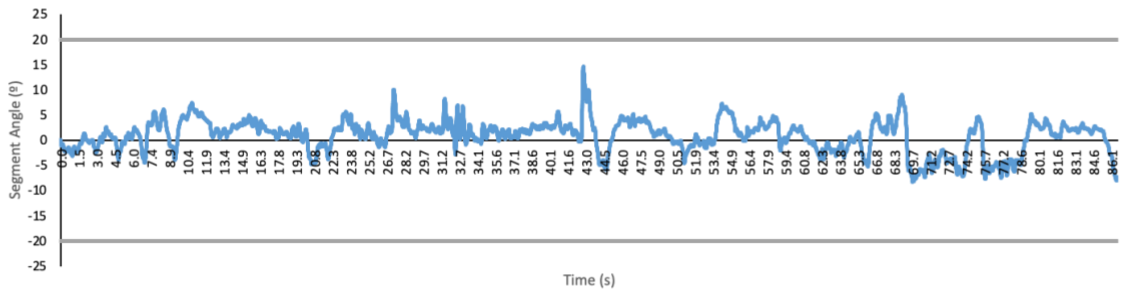



*Figure F.7.2 C07-13 Neck lateral bending time series with neutral ROM in grey*

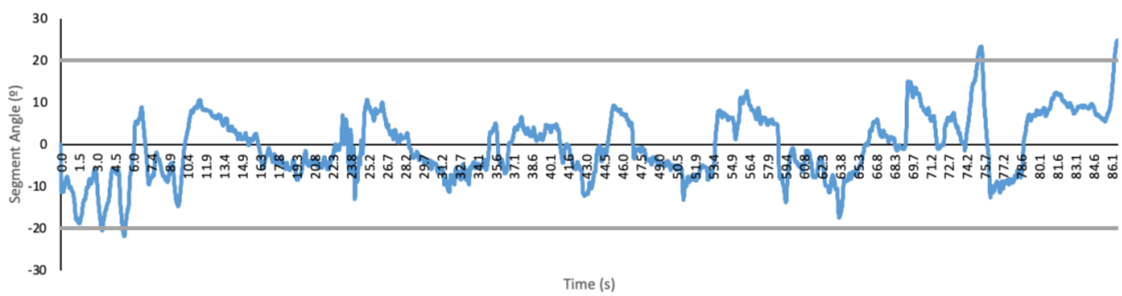



*Figure F.7.3 C07-13 Neck axial rotation time series with neutral ROM in grey*

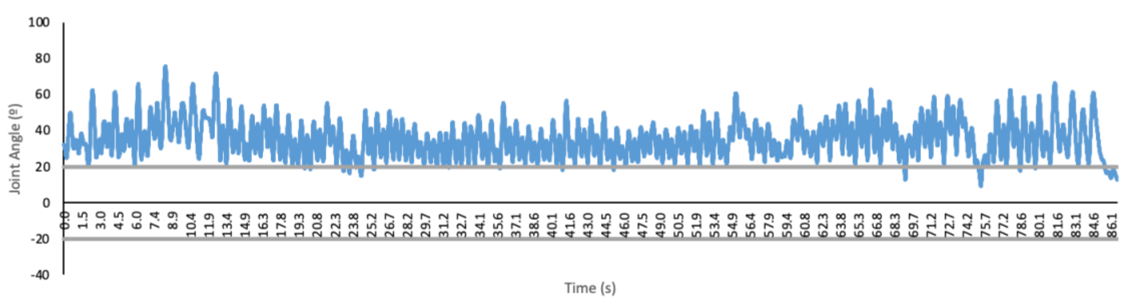



*Figure F.7.4 C07-13 Right shoulder flexion time series with neutral ROM in grey*

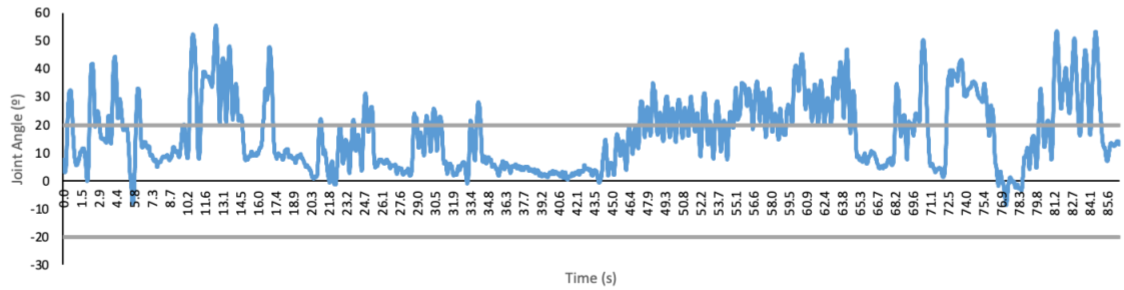



*Figure F.7.5 C07-13 Left shoulder flexion time series with neutral ROM in grey*

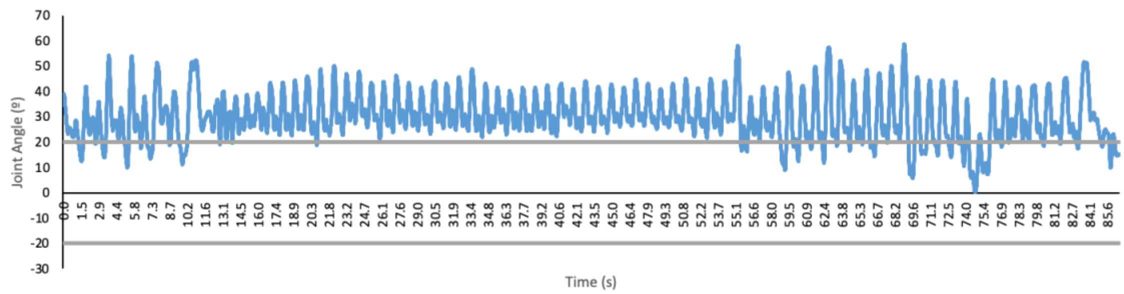



*Figure F.7.6 C07-13 Right shoulder abduction time series with neutral ROM in grey*

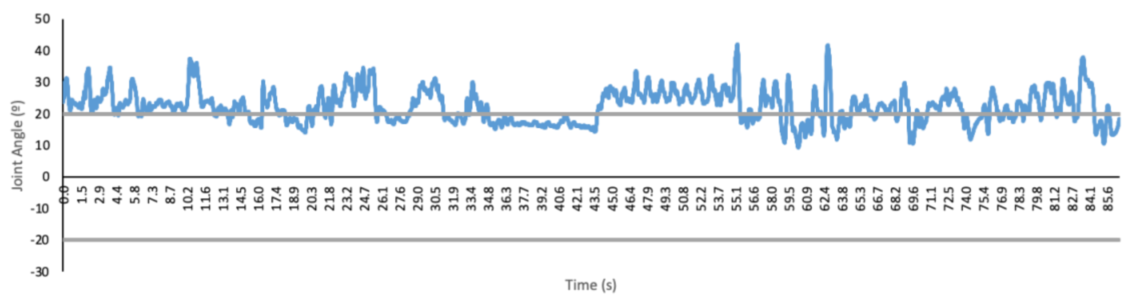



*Figure F.7.7 C07-13 Left shoulder abduction time series with neutral ROM in grey*

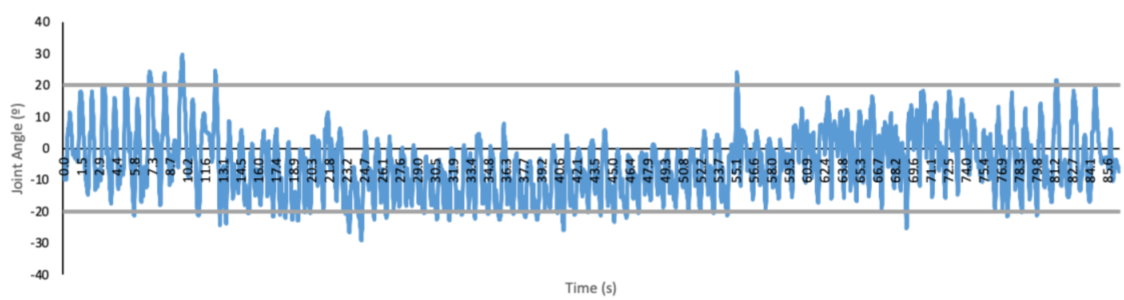



*Figure F.7.8 C07-13 Right shoulder rotation time series with neutral ROM in grey*

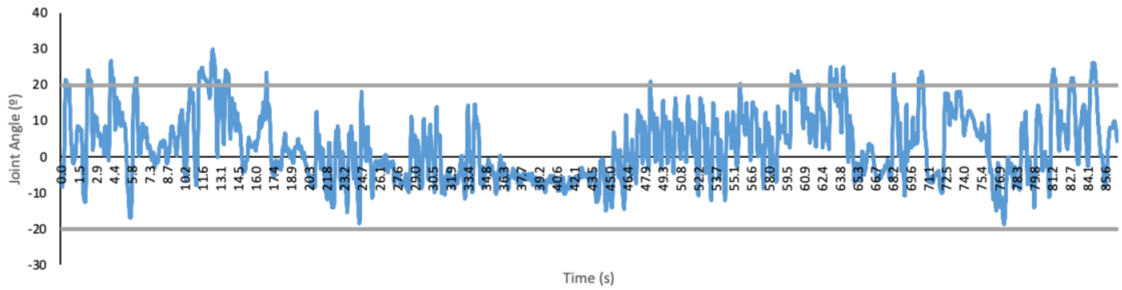



*Figure F.7.9 C07-13 Left shoulder rotation time series with neutral ROM in grey*

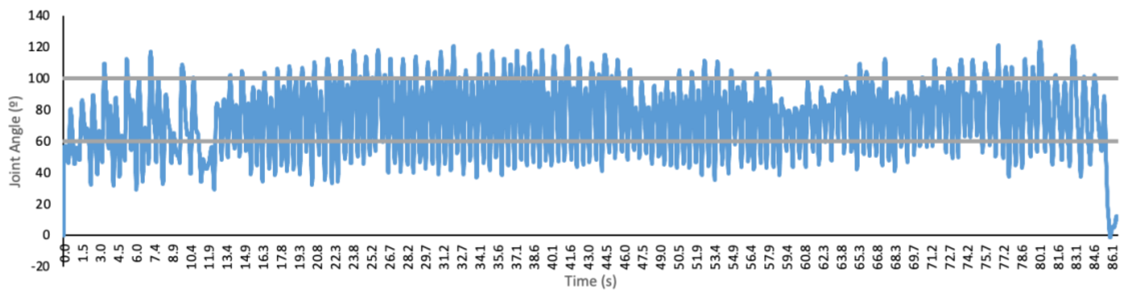



*Figure F.7.10 C07-13 Right elbow flexion time series with neutral ROM in grey*

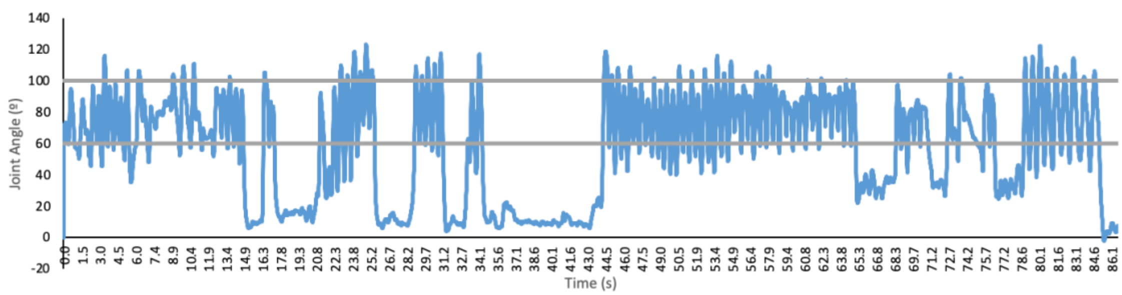



*Figure F.7.11 C07-13 Left elbow flexion time series with neutral ROM in grey*

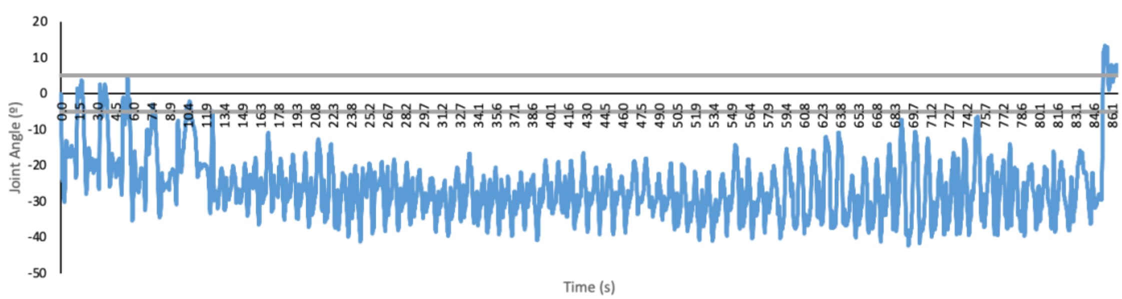



*Figure F.7.12 C07-13 Right wrist flexion time series with neutral ROM in grey*

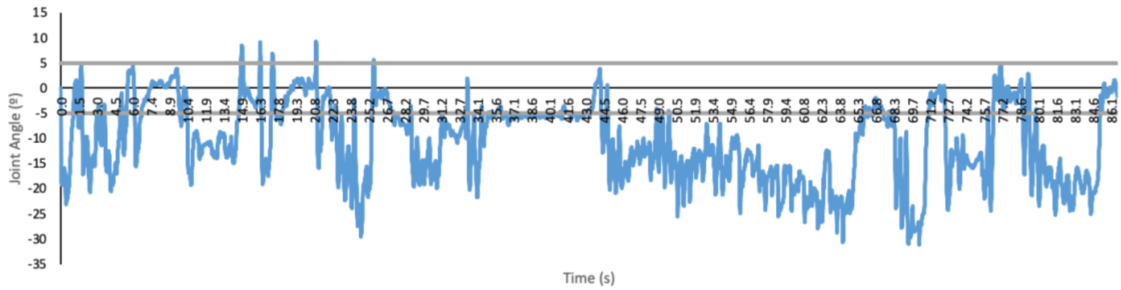



*Figure F.7.13 C07-13 Left wrist flexion time series with neutral ROM in grey*

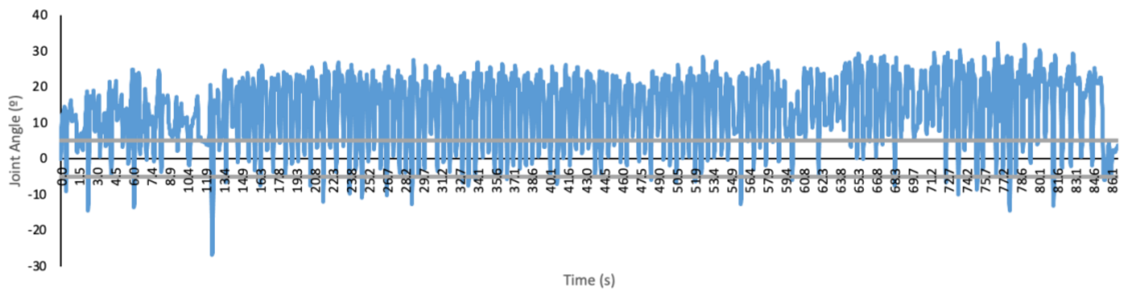



*Figure F.7.14 C07-13 Right wrist radial deviation time series with neutral ROM in grey*

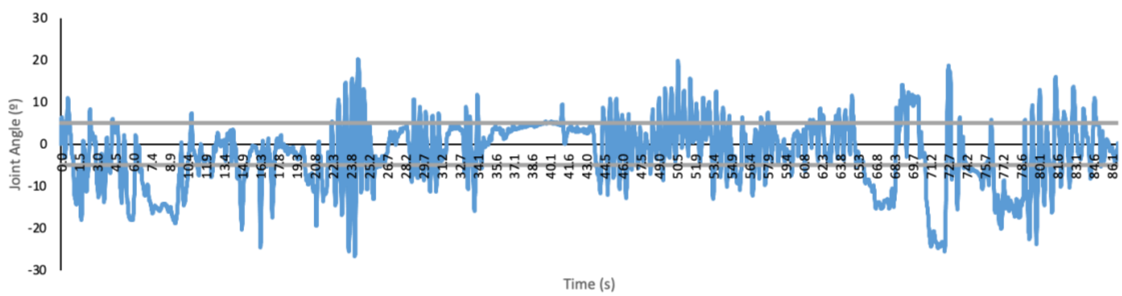



*Figure F.7.15 C07-13 Left wrist radial deviation time series with neutral ROM in grey*

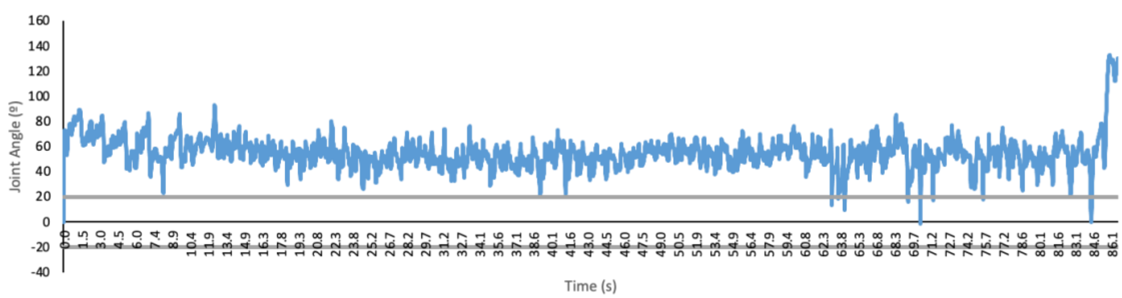



*Figure F.7.16 C07-13 Right wrist pronation time series with neutral ROM in grey*

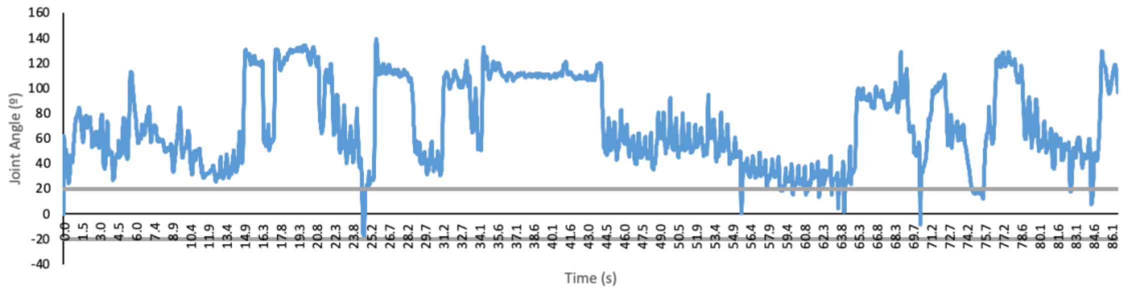



*Figure F.7.17 C07-13 Left wrist pronation time series with neutral ROM in grey*

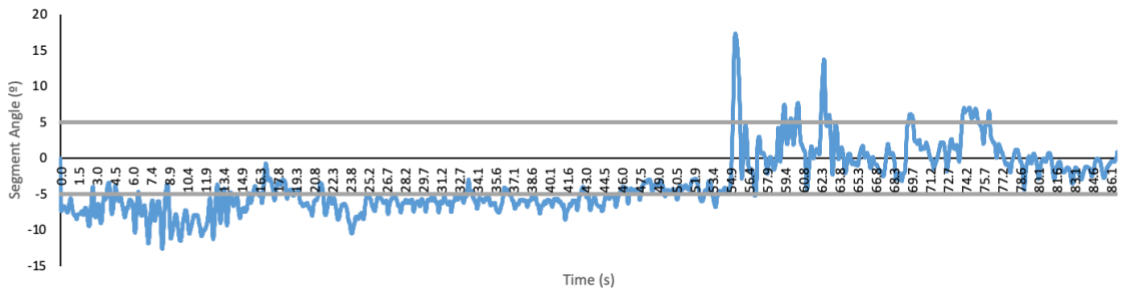



*Figure F.7.18 C07-13 Trunk flexion time series with neutral ROM in grey*

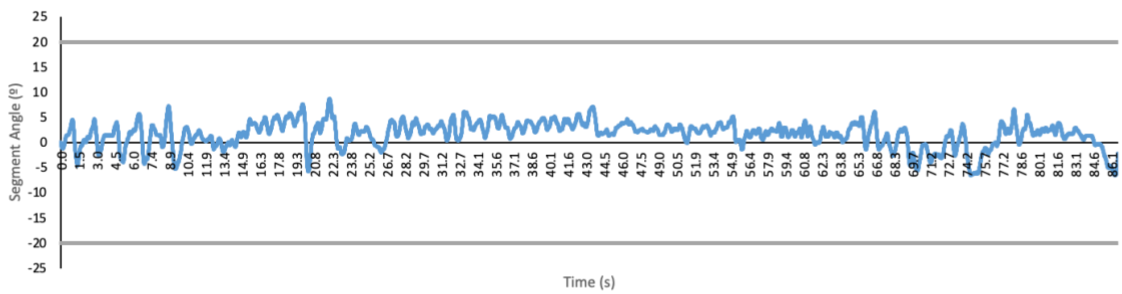



*Figure F.7.19 C07-13 Trunk lateral bending time series with neutral ROM in grey*

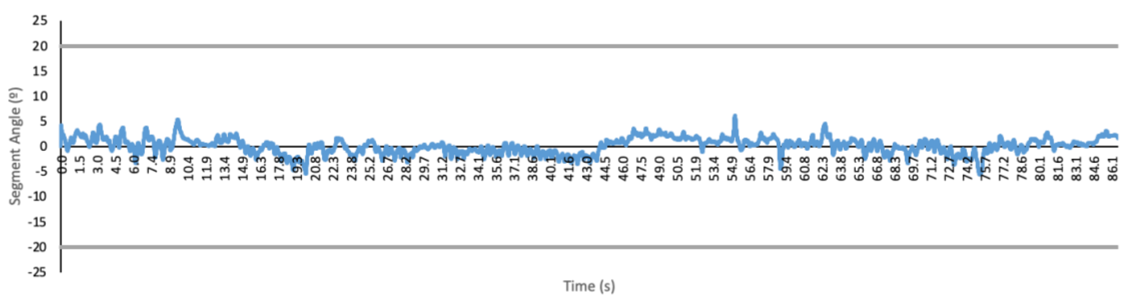



*Figure F.7.20 C07-13 Trunk axial rotation time series with neutral ROM in grey*

# VITA AUCTORIS

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|---|---|
| NAME: | Jessica Rosemary Flammia |
| PLACE OF BIRTH: | Windsor, ON |
| YEAR OF BIRTH: | 1996 |
| EDUCATION: | Vincent Massey Secondary School, Windsor, ON, 2014 |
| | University of Windsor, BHK, Windsor, ON, 2019 |
| | Fanshawe College, OCGC, London, ON, 2020 |
| | University of Windsor, MHK, Windsor, ON, 2024 |