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The effects of acute and 2 hour post-physical activity on the estimation of body fat made
by the Bod Pod

By:

Bradley J. Harrop

A Thesis
Submitted to the Faculty of Graduate Studies
Through the Faculty of Human Kinetics
in Partial Fulfilment of the Requirements for
the Degree of Master of Human Kinetics at the
University of Windsor

Windsor, Ontario Canada
2013

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by the Bod Pod

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Declaration of Originality

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Abstract

The Bod Pod has been found to be both reliable and valid against several criterion methods such as hydrostatic weighing, and dual energy x-ray absorptiometry, and under different conditions, such as clothing level, dehydrated states, and body temperature changes. However, questions still remain regarding the effects of an acute bout of exercise on the Bod Pod. Therefore, the purpose of this study was to determine the effects of an acute bout of exercise on the estimations made by the Bod Pod. Participants (15 males and 22 females) ranged in age from 18-27 years and were currently exercising. Height and weight were measured prior to entering the Bod Pod. Baseline Bod Pod measures were completed followed by a 30 minute cycling trial at 75% of heart rate max. Bod Pod measures were taken immediately following exercise and 2-hr post-exercise. Statistical differences between males and females were found at baseline between height ($p<0.001$), weight ($p<0.001$), body volume ($p<0.001$), and body density ($p<0.001$). Among males, body mass ($p<0.001$), %BF ($p<0.001$), and body volume ($p<0.001$) decreased while body density ($p<0.001$) and body temperature ($p<0.001$) increased directly following exercise; body mass ($p<0.001$) and body volume ($p<0.001$) remained lower 2-hr later. Among females, body mass ($p<0.001$) and body volume ($p<0.001$) decreased while TGV ($p=0.014$) and temperature ($p<0.001$) increased directly following exercise; body mass ($p<0.001$) and body volume ($p<0.001$) remained lower yet %BF ($p<0.001$) and body density ($p=0.006$) remained higher 2-hr post-exercise. These results suggest that a single bout of exercise immediately before Bod Pod testing seems to alter the estimate of %BF, and continues to affect the prediction 2 hours after exercise in females.

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Table of Contents

Declaration of Originality	iii
Abstract	iv
Acknowledgements	v
LIST OF TABLES	ix
LIST OF FIGURES	x
LIST OF APPENDICES	xi
LIST OF ABBREVIATIONS	xii
RESEARCH ARTICLE.....	1
Introduction.....	1
Methods.....	3
Participants and recruitment.....	3
BSA.	3
Bod Pod.	4
Study Procedures.....	5
Confirmation of the TGV Measurement	6
Effect of an acute bout of exercise on the estimations produced by the Bod Pod.....	7
Data Analysis	8
Results.....	8
Discussion	9
Limitations	11
Implications.....	12
Conclusions.....	13

References	14
REVIEW OF LITERATURE	26
Body Composition	26
What Is It?	26
Why Do We Care?	26
Body Composition Models and Levels	27
Five Levels of Body Composition.	27
Method Classification.	28
Measureable Component Categories.....	29
Compartment Models.....	29
Two-Compartment Model.....	29
Three-Compartment Model.....	30
Four Compartment Model.....	30
Types of Body Composition (overview).....	31
Dual Energy X-ray Absorptiometry	31
Near-infrared Interactance.....	33
Anthropometry	34
Bioelectrical Impedance	36
Hydrodensitometry.....	37
Air Displacement Plethysmography	39
Validity and Reliability	40
Validity and Reliability of DXA	41
Validity and Reliability of NII	42

Validity and Reliability of SFM.....	43
Validity and Reliability of BIA	45
Validity and Reliability of HD	46
Validity and Reliability of ADP	48
Conclusion	51
Influences on Body Composition.....	52
Gender	52
Physical activity	53
Hydration.....	55
Food/last meal	56
Clothing.....	56
Implication for current research	57
References	58
Appendix A.....	80
Appendix B	81

LIST OF TABLES

<i>Table 1:</i> A repeated measures analysis of variance and coefficients of variation (CV) of the 5 TGV trials among male (n=15) and female participants (n=21).....	21
<i>Table 2:</i> Basic demographics of all participants (n=37)	22
<i>Table 3:</i> Effects of exercise on the estimations made by the Bod Pod.....	23

LIST OF FIGURES

<i>Figure 1:</i> Illustrates the process in which the Bod Pod estimates %BF	24
<i>Figure 2:</i> Confidence intervals for 5 consecutive TGV trials among males (n=15) and females (n=21).....	25

LIST OF APPENDICES

APPENDIX A	Demographic, Health, and Physical Activity Questionnaire.....	93
APPENDIX B	Physical Activity Readiness Questionnaire	94

LIST OF ABBREVIATIONS

- %BF – Percentage Body Fat
- ACSM – American College of Sport Medicine
- ADP – Air Displacement Plethysmography
- BIA – Bioelectrical Impedance Analysis
- BMI – Body Mass Index
- BV – Body Volume
- BSA – Bodymedia Sensewear Mini Armbands
- CV – Coefficients of Variation
- Db – Body Density
- DXA – Dual Energy X-ray Absorptiometry
- FFDM – Fat Free Dry Mass
- FFM – Fat Free Mass
- FM – Fat Mass
- HD – Hydrodensitometry
- MET – Metabolic Equivalent
- NII – Near-infrared interactance
- PA – Physical Activity
- PACR – Physical Activity, and Cardiovascular Research
- PARQ – Physical Activity Readiness Questionnaire
- RMR – Resting Metabolic Rate
- RV – Residual Volume
- SD – Standard Deviation

SFM – Skinfold Measurement

TBW – Total Body Water

TGV – Total Gas Volume

Vb – Body Volume

Vb_{raw} – Body volume (raw)

WHR – Waist-to-hip Ratio

RESEARCH ARTICLE

Introduction

The study of modern human body composition is over 100 years old, spanning several disciplines such as clinical nutrition, sport and exercise science, and medicine (Heymsfield, Lohman, Wang, & Going, 2005). Body composition research is divided into three interconnected areas: the organizational rules that guide the different levels of body composition, their measurement techniques, and biological factors that influence body composition (Wang, Heshka, Pierson Jr., & Heymsfield, 1995). Body composition can be used to assess diet quality (Spagnoli, Costa, Caputo, & Cesari, 2012), disease status (Valerio et al., 2012), nutrition and its effects on disease (Lane, Magnon, Lane, Chan, Hoyt, & Greenfield, 2008), athletic performance (Ackland et al., 2012), weight-sensitive sports (Ackland et al., 2012; Brito, Martins-Roas, Brito, Marins, Cordova, & Franchini, 2012), malnutrition (Heymsfield, McManus, Stevens, & Smith, 1982), the administration of drug dosages (Wulfsohn & Joshi, 1969), and muscle and bone atrophy during prolonged periods of immobilisation or bed rest.

Several techniques exist to estimate body fat percentage (%BF), including dual energy x-ray absorptiometry (DXA; Wang, Heymsfield, Chen, Zhu, & Pierson, 2010; Pietrobelli, Formica, Wang, & Heymsfield, 1996), skinfold measurements (Heymsfield et al., 2005), near infrared interactance (NII; American College of Sports Medicine; ACSM, 2010), and hydrodensitometry (HD; Wagner & Heyward, 2001; Ward, Pollock, Jackson, Ayres, & Pape, 1978). Developed in the 1990's, the Bod Pod (McCrory, Gomez, Bernauer, Mole, 1995) is very similar to HD except it uses air displacement to make an

estimation of body density (Db) in lieu of water displacement (Dempster & Aitkens, 1995).

The manufacturer of the Bod Pod currently recommends that individuals not eat, drink, or participate in any physical activity 2-hr prior to undergoing Bod Pod testing. This is an attempt to ensure that all individuals undergoing testing are at a normal and rested state prior to testing, as deviation in both body temperature and hydration status may affect the measurement made by the Bod Pod. Fields, Higgins, & Hunter (2004) examined the effects of body temperature and moisture between Bod Pod trials (using HD), and reported that Db (0.01g/cm^3) and body weight (0.8kg) significantly increased, while corrected body volume (BV; 0.2L) and %BF (1.79%) significantly decreased after an increase in body temperature ($\sim 0.6^\circ\text{C}$). Further, changes in the Bod Pod's outcome measures can also be likely manipulated via a decrease in hydration status. For example, Utter et al. (2003) reported an increase of 0.9%BF using the Bod Pod after participants were instructed to decrease their body mass by 2-3%.

Although the Bod Pod has been used to determine the effects of an exercise intervention in several studies (da Silva et al., 2011; Plasqui, Soenen, Westerterp-Plantega, & Westerterp, 2011; Malavolti, Battistini, Dugoni, Bagni, Bagni, & Pietrobelli, 2008), to the authors knowledge, the effects of an acute bout of exercise on the Bod Pod's ability to estimate %BF has not been examined. Therefore, the purpose of this study was to determine the effects of an acute bout of exercise on the Bod Pod's ability to estimate %BF.

Methods

The University of Windsor Research Ethics Board approved all procedures (REB #12-171).

Participants and recruitment

Male (n=18) and female (n=27) participants were recruited from the University of Windsor through classroom visits, word of mouth, and a mass email sent throughout the department of Kinesiology. Participants (n=45) were determined to be current exercisers, between the ages of 18-28 years, who have not competed in varsity sports in the past two years. Exercise frequency and intensity were established using a Demographic, Health, and Physical Activity Questionnaire (see Appendix A) and physical activity was then validated using the Bodymedia Sensewear Mini (BSA; Pittsburgh, PA).

Of the 18 male participants, only 2 were unable to produce a valid thoracic gas volume (TGV) measurement(s) and did not complete the study. Of the 27 female participants, 4 individuals voluntarily withdrew, 1 was deemed not physically active, and 1 was removed from the exercise portion of the study as they were unable to produce a valid TGV measurement post exercise.

BSA. The BSA was used to validate physical activity responses collected via the Demographic, Health, and Physical Activity Questionnaire. The BSA has been validated among several populations including adults between the ages of 18-60 years (Fruin & Rankin, 2004; Johannsen, Calabro, Stewart, Franke, Rood, & Welk, 2010) and children between 11-15 years of age (Arviddson, Slinde, & Hulthen, 2009; Dorminy, Choi, Akohoue, Chen, & Buchowski, 2008). In one study of 30 adults over 14 days, the armbands measured total energy expenditure to within 22 kcal/day compared to doubly

labeled water, the current gold standard for measuring energy expenditure (Johannsen et al., 2010). The BSA has been shown to be valid at low to moderate-intensity activities (Fruin & Rankin, 2004; King, Torres, Potter, Brooks, & Coleman, 2004), and is well suited for evaluating activity levels in the general public. The BSA device (similar to a pedometer/accelerometer yet more sophisticated) is a small monitor that is worn on the upper left arm (over the triceps) and measures biaxial accelerometry, body heat loss, and galvanic skin response which automatically calculates minute by minute total energy expenditure and metabolic equivalents (METs). There is no discomfort associated with wearing the BSA and it can easily be worn under clothing. Participants were deemed active if they exceeded three METs for more than 30 minutes a day. This device was not able to collect data from three participants (e.g., time on body was less than 20 hours/day) so the questionnaire was used to determine suitability in the current study.

Bod Pod. A full description of the Bod Pod (Life Measurement, Inc., Concord, CA) can be found in Fields, Goran, & McCrory (2002), Dempster & Aitkens (1995), and McCrory, Gomez, Bernauer & Mole (1995). As a short summary (Figure 1), prior to entering the Bod Pod, body weight is taken via the electric scale. Participants then enter the Bod Pod for two separate BV measures. If the two tests measures differ by more than 150mL, a third test occurs. At the end of this stage, a raw BV ($V_{b_{raw}}$) is determined. However, because air in the lungs behaves isothermally (i.e., air in the lungs is 40% more compressible than air under adiabatic conditions), a measure of TGV is needed. After several cycles of normal breathing, participants are instructed to breathe normally through the breathing tube in accordance with a progression bar on the screen (i.e., to measure tidal volume), followed by instructions to huff (e.g., gentle puff) three times

(i.e., to measure functional residual capacity). Using a proprietary formula, TGV is estimated using half of tidal volume plus the functional residual capacity. Once completed, TGV is then used as a correction factor to determine a corrected BV. This is then used, along surface area artefact (i.e., a correction factor to account for the warm air nearest the skin), to determine Db. Once Db is calculated, it is then applied to the %BF formula developed by Siri (1961).

In the past, the Bod Pod's ability to estimate %BF has been validated against several criterion methods including DXA (Ballard, Fafara, & Vukovich, 2004; Bentzur, Kravitz, & Lockner, 2008) and HD (Levenhagen et al., 1999; Wagner, Heyward, & Gibson, 2000) showing good to excellent correlation of 0.89-0.91 and 0.88-0.92, respectively (Bentzur et al., 2008; Koda, Tsuzuku, Nino, & Shimokata, 2000; Miyatake, Nomaka, & Fujii, 1999; Wagner et al., 2000). The Bod Pod has also shown good validity in female Division II collegiate athletes (n=12) and controls (n=10) compared to DXA, reporting no significant differences in %BF between two consecutive trials (Ballard et al., 2004). Similar results were also observed among collegiate football players (Collins et al., 1999) and in adults of various ethnicities (McCrory et al., 1995; Sardinha, Lohman, Teixeira, Guedes, & Going, 1998).

Study Procedures

All participants were asked to report to the Physical Activity and Cardiovascular Research (PACR) Lab located in the Human Kinetics building at the University of Windsor for an initial meeting. Informed consent was obtained, and the Demographic, Health, and Physical Activity Questionnaire (Appendix A) and the Physical Activity Readiness Questionnaire (PARQ; Appendix B) were filled out. Height and weight were

measured using a wall mounted tape measure (height) and the electronic scale from the Bod Pod (weight), and participants were asked to undergo a familiarization trial in the Bod Pod prior to being fitted with a BSA. The BSA was worn at all times with the exception of showering and swimming for the subsequent 7 days.

Participants were then asked to return to the PACR lab at a later date to complete data collection. All participants were instructed to refrain from eating/drinking and participating in physical activity for two hours prior to testing (as per manufacturer's specifications). As female participants were included in this study, it was prudent to standardize the phase of menstrual cycles (Francek, 2008; Symons, Sowers, & Harlow, 1997; Meijer, Westerterp, Saris, & ten Hoor, 1992). All female participants were asked to return to the PACR lab 3-5 days after completion of menses, thus attempting to ensure all female participants were within the same phase (Follicular phase) of their menstrual cycle.

Confirmation of the TGV Measurement

Due to observed difficulties in obtaining a measured TGV using the Bod Pod in the PACR lab at the University of Windsor and the known difficulties reported in the literature (Anderson, 2007), a confirmatory methodology was done to assess the stability of the TGV measure (i.e., in order to determine whether to measure TGV in the subsequent study). Five consecutive Bod Pod tests (i.e., BV and TGV measurements) were completed back to back using the current study's participants. Descriptive statistics were used to confirm the stability of the TGV measurement over 5 trials (Figure 2), and individual repeated measures *ANOVAs* were used to assess TGV, %BF, BV, and body mass over the 5 trials, separately by gender (Table 2). Multiple pairwise comparisons

were used compare each trial against Trial 5 as the reference/criterion measure. Trial 5 was chosen as the reference/criterion measure under the basic assumption that as participants became more comfortable with the testing protocol (i.e., TGV measurement), their results would be more accurate. Coefficient of variation for repeated measures (CV) were calculated for each measure as $(SD/X)*100$, where SD is the mean of the standard deviation of the repeated trials, and X is the mean of the repeated trials (Noreen and Lemon, 2006).

Figure 2 illustrates the confidence intervals and means for each of the 5 trials by gender, suggesting a relatively stable TGV measure. Among males, no statistical differences were found among any of the measures, however, differences were observed for %BF ($p<0.004$), BV ($p<0.004$), and body mass ($p<0.001$) for females over the 5 trials. Overall, the CV for %BF was 7.29% and 6.77% for males and females, respectively. Interestingly, TGV was not statistically significant between the trials for either gender. Therefore, the present results support Anderson's (2007) work and the use of measuring TGV during subsequent trials.

Effect of an acute bout of exercise on the estimations produced by the Bod Pod

Prior to beginning exercise, participants were asked to change into exercise attire, including undergarments. Each participant was asked to exercise at 75% of heart rate maximum ($220-\text{age}$) for 30 minutes on a cycle-ergometer. Heart rate was monitored using the Polar heart rate system (model # E40) which includes a transducer that wraps around the participant's thorax and a display watch so that both the participant and researcher could monitor the heart rate. Upon completion, the participants were immediately instructed to change into their original Bod Pod clothing (i.e., to eliminate

any error caused by sweat collected in clothing which would have been worn in the Bod Pod) and wipe away any sweat on the body. Prior to entering the Bod Pod, a second body temperature reading was taken.

Once the Bod Pod testing was completed, the participants were given a mouthful of water. Participants were instructed not to consume any additional water or food and were asked to return to the PACR lab two hours later. Upon the return of the participant to the PACR lab, a third body temperature measurement was taken, followed by a final Bod Pod.

Data Analysis

Data collected during this study were analysed using SPSS software for Windows (v21.0, Armonk, NY). All analyses were completed separately for males and females. Basic demographics were assessed using independent *t-tests* (Table 2). The effects of exercise on the Bod Pods ability to estimate %BF was analysed using separate within-subjects repeated measures *ANOVA* to determine the differences between %BF, Db, BV, body mass, TGV, and body temperature over time (Table 3). Trial 5 (from the confirmation portion of this study) was used as the *baseline* measurement to determine the effects of exercise on the estimations produced by the Bod Pod.

Results

Basic demographics and measurements taken from baseline are presented in Table 2. Age ranged from 18-27 years (males 18-27, females 19-23). Significant differences between males and females were found in relation to height ($p < 0.001$), body mass

($p < 0.001$), TGV ($p < 0.001$) and BV ($p < 0.001$). No significant differences between males and females in reference to %BF and fat free mass (percent) were observed. Males and females wore the BSA devices for an average of 22 hours, respectively, suggesting good compliance with this methodology.

Among males and females, significant differences were found across baseline, post-exercise, and 2hr post-exercise (see Table 3) for body mass ($p < 0.001$), %BF ($p < 0.001$), Db ($p < 0.001$ males and $p = 0.006$ females), BV ($p < 0.001$), and temperature ($p < 0.001$). Additional differences were also seen in TGV ($p < 0.014$) for females only.

Discussion

Although the Bod Pod has been widely utilized for research purposes to determine the effects of exercise interventions (da Silva et al., 2011; Plasqui, et al., 2011; Malavolti, et al., 2008), questions still remain regarding the length of time needed between exercise and Bod Pod testing. The purpose of this study was, therefore, to determine the effects of an acute bout of physical activity on the ability of the Bod Pod to estimate %BF.

Several significant differences were found between baseline, post exercise, and 2hr post exercise (Table 3). When considering the changes in body mass, this could be due to the loss of water as a by-product of exercise (sweating; Sawka, Burke, Eichner, Maughan, Montain, Stachenfeld, 2007). It is generally accepted that for every kilogram lost from a pre-exercise weight that the body's hydration status decreases by 1-2% (Coyle, 1995). Water is typically lost through sweat and during respiration. This may explain the decreased body mass seen immediately after exercise in both males and female (i.e., -0.39kg and -0.26kg, respectively), which in turn could affect the %BF

measurement. Utter et al. (2003) found that a decrease in hydration of 2-3% resulted in a decrease in total body mass of 2 kg or 2.6% body weight. The current study did not replace water lost (rather gave each participant a small mouthful of water), which may explain why body mass did not return to normal even 2 hours later. In fact, body mass was -0.55kg (males) and -0.38kg (females) lower 2-hr post-exercise. A possible explanation for this may have been the time between the subjects last meal (e.g., may have also decreased the subject's weight). Although, all subjects were given the same instructions, some participants may have been in a fasted state for longer than others.

Significant changes were also observed for BV in both males and females. A potential explanation for these differences might be the changes in body temperature during the testing period (e.g., body temperature increased with the exercise protocol). The current results are similar to those found by Fields et al. (2004), who reported a decrease in BV following an increase in body temperature of $\sim 0.6^{\circ}\text{C}$. Fields et al. (2004) argued that the changes in body temperature may have been too rapid (i.e., half a degree in 30 minutes) for the correction factors used by the Bod Pod to take effect.

Finally, there were also several significant changes in %BF for both males and females (although the pattern differed). The decrease in males could be a by-product of the increased temperature changes (discussed earlier). Fields et al. (2004) observed a decrease in both %BF and BV (corrected), while Db and body mass increased when the participant was warmed. As Db is function of body mass, BV, changes in these variables would inevitably affect %BF. Once temperature returned to normal (2-hr post-exercise), %BF returned to baseline. Among females, %BF significantly increased 2-hr post-exercise. The increase in %BF among females may be a function of the higher TGV

values observed. Once again, Fields et al. (2004) also measured TGV but did not report a significant difference between TGV trials. As TGV was the only variable that was different between the patterns observed by males and females, it is plausible that the increase in TGV may have caused the %BF to be higher in females 2-hrs post-exercise. Although the results of this study have some practical implications, the results fall within the error rates reported in Table 1 as CV's. Therefore, it cannot be stated with certainty that these results are due to exercise alone and not caused by the error associated with the Bod Pod.

Limitations

As not all variables can be controlled for, there are several limitations to this study. The first of these limitations is that a reliable and valid tool to measure hydration levels was needed. As the intervention was exercise-based, and water loss is expected, it is only prudent that some measure of hydration be used. The only tool that was available at the time was a bioelectrical impedance apparatus. Although generally speaking, bioelectrical impedance is a good technique to detect hydration levels, this particular tool had only been validated to determine %BF and not water levels. However, we did try to account for some water loss by giving each participant a mouthful of fluid replacement after exercise. The current study also did not necessarily account for human waste during the 2 hour period not in the lab. It is possible that participants may have voided during that time, thus altering hydration levels and/or body mass.

The second limitation is the time spent fasting. Although all subjects, theoretically, fasted for the same amount of time during our study protocol (~five hours

were spent in a fasted state), the time of last meal was not recorded so some individuals may have fasted for longer than others (prior to the onset of the study). In the future, it is recommended that time of last meal be noted and/or the type/quantity/quality of the last meal be standardized.

Implications

The Bod Pod is a quick (~5 minutes/test), inexpensive, tool to estimate %BF that requires little technical expertise to operate it, and is more comfortable for participants (compared to HD and DXA). The current findings suggest that moderate bout of exercise is enough to alter %BF readings made by the Bod Pod. Although the differences did not exceed the current error rates reported in Table 2, practically speaking, if an individual wanted to alter their %BF, a single bout of moderate-intensity exercise would alter the results.

When considering the TGV measurement made by the Bod Pod, this study confirms findings reported by Anderson (2007) implying that the TGV measure is stable. However, given the cost associated with the TGV measure, the difficulties reported in both Anderson (2007), and the significant difference observed by females in the present study, it is suggested that predicted values be used in future estimations to decrease variability with test-retest situations. This will decrease testing time, frustration on the part of the participant, as well as the cost of future research.

Conclusions

The main objective of this study was to determine the effects of an acute bout of exercise on the Bod Pod's ability to estimate %BF. When examining the data from the effects of exercise on the Bod Pod's ability to predict %BF, it is clear that the current recommendation put forth by Cosmed (refraining from any physical activity for 2 hours) is not enough time for the Bod Pod to measure an individual under resting conditions. If an individual wished to manipulate their %BF measurement in order to gain a competitive advantage, a moderate bout of exercise lasting only 30 minutes would be sufficient to influence the %BF. Therefore, it is suggested that future research examine the necessary time needed for the body to return to resting levels so that accurate measurements of %BF are taken.

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Table 1: A repeated measures analysis of variance and coefficients of variation (CV) of the 5 TGV trials among male (n=15) and female participants (n=21)

		Trial 1 Mean (SD)	Trial 2 Mean (SD)	Trial 3 Mean (SD)	Trial 4 Mean (SD)	Trial 5 Mean (SD)	<i>F</i> - value	Significance (<i>p</i> -value)	CV
Males (n=15)	Body fat (%)	22.03 (7.44)	20.75 (7.71)	21.37 (8.18)	21.81 (7.52)	21.72 (7.78)	5.23	0.051	7.29
	Body volume (L)	83.35 (11.23)	83.11 (11.23)	83.22 (11.30)	83.28 (11.20)	83.24 (11.26)	2.44	0.057	0.26
	Body mass (kg)	87.32 (10.95)*	87.30 (10.95)	87.30 (10.94)	87.29 (10.94)	87.25 (10.91)	4.06	0.067	0.03
	TGV (L)	4.18 (0.81)	4.08 (0.74)	4.06 (0.77)	4.09 (0.69)	4.09 (0.71)	0.54	0.709	5.49
Females (n=21)	Body fat (%)	26.21 (6.75)	24.81 (7.50)	24.42 (7.70)	24.38 (7.05)*	25.09 (7.12)	5.38	0.004	6.77
	Body volume (L)	57.83 (8.03)*	57.66 (7.98)	57.62 (8.01)	57.60 (7.99)*	57.69 (8.03)	5.41	0.004	0.32
	Body mass (kg)	60.05 (7.75)*	60.04 (7.75)*	60.04 (7.75)*	60.03 (7.75)*	60.03 (7.75)	55.59	0.008	0.01
	TGV (L)	3.12 (0.43)	3.07 (0.44)	3.11 (0.49)	3.04 (0.45)	3.15 (0.48)	0.75	0.508	6.13

* indicates a significant difference between individual trial and baseline (trial 5) using multiple pairwise comparisons, $p < 0.05$

Table 2: Basic demographics of all participants (n=37)

	Males (n=15) Mean (SD)	Females (n=22) Mean (SD)	Significance p-value
Age (years)	21.92 (2.49)	21.04 (1.15)	0.206
Height (m)	1.79 (7.56)	1.63 (8.12)	<0.001
Body Mass (kg)	86.40 (10.40)	59.61 (7.81)	<0.001
Body fat (%)	20.36 (7.44)	24.6 (7.31)	0.187
Fat Free mass (%)	79.64 (7.44)	75.40 (7.31)	0.195
TGV (L)	4.16 (0.86)	3.13 (0.47)	<0.001
Body volume (L)	82.20 (10.70)	57.24 (8.11)	<0.001
Time physically active (hours/day)	2.94 (1.27)	3.42 (1.62)	0.356

Table 3: Effects of exercise on the estimations made by the Bod Pod

		Baseline Mean (SD)	Post-exercise Mean (SD)	2hr post-exercise Mean (SD)	Significance (p-value)
Males (n=15)	Body mass (kg)	87.17 (10.55)	86.78 (10.57)*	86.62 (10.62)*	<0.001
	Body fat (%)	21.15 (7.58)	18.81 (9.04)*	21.61 (8.25)	<0.001
	Body density (kg/L)	1.051 (0.01)	1.056 (0.02)*	1.050 (0.02)	<0.001
	TGV (L)	4.22 (0.86)	4.39 (0.82)	4.34 (0.96)	0.348
	Body volume (L)	83.06 (10.90)	82.28 (10.92)*	82.62 (11.03)*	<0.001
	Temperature (°C)	35.65 (0.65)	36.27 (0.69)*	35.69 (0.55)	<0.001
Females (n=21)	Body mass (kg)	59.44 (7.95)	59.18 (7.97)*	59.06 (7.95)*	<0.001
	Body fat (%)	24.74 (7.45)	24.20 (7.24)	25.95 (7.29)*	<0.001
	Body density (kg/L)	1.043 (0.02)	1.044 (0.02)	1.040 (0.02)*	0.006
	TGV (L)	3.13 (0.48)	3.27 (0.42)*	3.09 (0.49)	0.014
	Body volume (L)	57.09 (8.28)	56.77 (8.23)*	56.86 (8.19)*	<0.001
	Temperature (°C)	35.77 (0.59)	36.3 (0.57)*	35.69 (0.55)	<0.001

* indicates significant difference between baseline and trial using pairwise comparisons, $p < 0.05$

Figure 1: Illustrates the process in which the Bod Pod estimates %BF

Figure2: Confidence intervals for 5 consecutive TGV trials among males (n=15) and females (n=21)

REVIEW OF LITERATURE

Body Composition

What Is It? The study of modern human body composition is over 100 years old, spanning several disciplines including clinical nutrition, sport and exercise science, and select areas of medicine for the purposes of research and diagnostics (Heymsfield, Lohman, Wang & Going, 2005). Body composition research is a sub-discipline of human biology, and consists of three interconnecting areas: the organizational rules that guide the different levels of body-composition, their measurement techniques, and biological factors that influence body composition (Wang, Heshka, Pierson Jr., & Heymsfield 1995). However, the main focus of this review will be the measurement techniques.

The fundamental concept of body composition analysis can be described as the attempt to determine the structure of an unknown compartment by measureable quantities within the compartment. This can be expressed mathematically as:

$$C = f(Q) \tag{1}$$

where C is the unknown compartment, Q is the measurable quantity and f is the mathematical function relating both C and Q together (Wang et al., 1995). The measureable component of equation 1 can be further sub-divided into two categories: the compartment's measureable property and the known component (Heymsfield et al., 2005), both of which are discussed later in this review.

Why Do We Care? Body composition research allows investigators to examine the various components which comprise the human body (Heymsfield et al., 2005). This examination can be for research in diet quality (Spagnoli, Costa, Caputo, & Cesari,

2012), assessment of disease status (Valerio et al., 2012), nutrition and its effects of disease processes (Lane, et al., 2008), and athletic performance (Ackland et al., 2012).

When considering weight-sensitive sports, it is important to monitor athletes as they may take extreme measures in order to gain a competitive advantage (Ackland et al., 2012; Brito et al., 2012). These measures can be detrimental to the athlete's health (Ackland et al., 2012), and may limit their overall performance by decreasing muscular strength (Ftaiti, Grelot, Coudreuse, & Nicol, 2001), performance time in aerobic activities (Stohr et al., 2011), and in some instances, may be fatal (Centers for Disease Control and Prevention, 1998; Forte, Precoma-Neto, Neto, Maia, & Faria-Neto, 2006). Furthermore, rapid weight loss can impact cognitive function (Choma, Sforzo, & Keller, 1998; Landers, Arent, & Lutz, 2001), as well as, increase the risk of the development of eating disorders when weight loss becomes an obsession (Rouveix, Bouget, Pannafieux, Champely, & Filaire, 2007).

Body composition is also important to the general population. It can be used in the assessment of malnutrition (Heymsfield, McManus, Stevens, & Smith, 1982), and the administration of drug dosages (Wulfsohn & Joshi, 1969).

Body Composition Models and Levels

Five Levels of Body Composition. Body composition research involves the study of components that are organized into five levels, with each level of growing complexity (Wang et al., 1995). These levels are: atomic, molecular, cellular, tissue systems and whole body (Wang et al., 1995). The atomic level consists of the essential building blocks for human life, such as carbon, hydrogen, and nitrogen (Wang et al., 1995). At the molecular level, the body is comprised of water (extracellular, intracellular

fluids), lipids (nonessential and essential fats), proteins, and minerals (Wang et al., 1995). It's at this level that most compartment models are derived from (e.g., 2- 3- and 4- compartment models; Wang et al., 1995).

The cellular level holds the necessary characteristics of life including metabolism, growth, and reproduction (Wang, Pierson Jr, & Heymsfield, 1992). At the tissue level, cells of the same shape, structure, and function combine resulting in the formation of connective, muscle, and epithelial tissues to name a few (Wang et al., 1995). Finally, the whole body level is the accumulation of the aforementioned levels to create the individual. At this level, the body can be divided into anatomical segments such as the head, trunk, and appendages, rather than discrete components. Anthropometric measurements can be used in several methods of body composition testing; such as skinfold and circumference measurements (Heymsfield et al., 2005).

Method Classification. Modern body composition analysis has been derived from three standard approaches; (1) direct or in vitro, (2) indirect, and (3) doubly indirect or in vivo methods (Wang et al., 1995). The direct method is not suitable for living subjects as it requires the dissection of the body for direct analysis of each component. Therefore, the latter methods are preferred and will be the continued focus of this review. Indirect methods such as hydrodensitometry (HD), use constants and rules based knowledge gained via the direct methods. Doubly indirect methods (e.g., skinfold measures) are derived from statistical relationships between easily measurable body parameters and a body composition component as measured by an indirect method (Deurenberg & Deurenberg-Yap, 2003). Because of this, there is more inherent error in

doubly indirect methods compared to the direct methods as they are based on assumptions of the indirect method (Wang et al., 1992; Wang et al., 1995).

Measureable Component Categories. All in vivo methods of determining body composition can be organized by measurable quantities into three categories: property-based, component-based, and a combination of both (Wang et al., 1995). The property-based method allows for an unknown component to be quantified from a measureable element (Wang et al., 1995). Bioelectrical impedance (BIA) and skinfold thickness (discussed later) are examples of this. However, sometimes two known properties are used to determine composition. For example, HD uses both body volume and body mass to determine fat (FM) and fat free mass (FFM; Brozek, Grande, Anderson, & Keys, 1963). Alternatively, the component-based method uses known properties to determine composition. Thus, the component based method must first be constructed using the property method. An example of this is fat free body mass can be derived from total body water by assuming that 73% of FFM is water (Wang et al., 1995). The final method utilizes a combination of both known components and measureable properties (Wang et al., 1995). An example of this would be the method for determining body fat from body mass and volume (measureable properties) and a known component (total body water; Siri, 1961; Wang et al., 1995).

Compartment Models

Two-Compartment Model. One of the most common compartment models is the two-compartment model, originally developed by Siri (1961) and Brozek et al. (1963). This model divides the body into two general areas, FM and FFM. FM is

comprised of fat or adipose tissue, while FFM is predominately water, proteins, and minerals (Siri, 1963; Wagner & Heyward, 2001). There are three main assumptions regarding the Siri two-compartment model: (1) density of fats (0.901 g/cc) and FFM (1.10 g/cc) are similar for all individuals, (2) density and relative quantity of proteins, water, and mineral components in FFM are consistent in all individuals, and (3) individuals only differ in the amount of adiposity compared to the *reference body* (Heyward, 2001). Alternatively, the Brozek two-compartment model assumes different densities for fats (0.88876 g/cc) and FFM (1.10333 g/cc) and is based on a *reference body* with a specific body density (D_b ; Brozek et al., 1963; Wagner & Heyward, 2001). Although both of these formulas differ from one another, the final percent body fat (%BF) estimates only differ 0.5%-1.0% BF for total D_b ranging from 1.0300 to 1.0900 g/cc (Wagner & Heyward, 2001).

Three-Compartment Model. Similar to the two-compartment model, the three-compartment model divides the body into, as the name suggests, three components. Although there may be several three-compartment models, the basic model includes FM, and FFM, whereby FFM is further sub-divided into fat free dry mass (FFDM) and total body water (TBW), which accounts for the largest component of the body (Malina, Bouchard, & Bar-or, 2004).

Four Compartment Model. The four-compartment model is the leading reference method for body composition (Ackland et al., 2012). The basic concept of this model builds on the previous compartment models, dividing FFDM into bone mineral and residual (Malina et al., 2004). This model typically assumes that the body is made up of FM, FFM, bone, and total body water (TBW; Ackland et al., 2012). There have been

~13 different equations developed with differing assumptions to predict %BF mainly dependent on age and gender of the participant/population (Ackland et al., 2012; Heymsfield et al., 2005). Based on the aforementioned compartment models, several techniques have been developed to estimate %BF.

Types of Body Composition (overview)

Dual Energy X-ray Absorptiometry

Dual Energy X-ray Absorptiometry (DXA) is part of a group of diagnostic methods referred to as photon-absorptiometry. Introduced in the 1960's, single photon-absorptiometry was used as a means to estimate appendicular bone mass for the evaluation and assessment of osteoporosis and soft tissue (Cameron & Sorenson, 1963; Pietrobelli, Formica, Wang, & Heymsfield, 1996; Wang, Heymsfield, Chen, Zhu, & Pierson, 2010), and utilized Iodine¹²⁵ as its photon source (Heymsfield et al., 2005). Later, in the 1980's this method added an additional wave length to its spectrum to become dual photon-absorptiometry. DXA was then developed after the radioactive source was converted to an X-ray beam with a filter that could convert the polychromatic X-ray beam into low and high energy peaks (Pietrobelli et al., 1996; Heymsfield et al., 2005).

The underlying concept of DXA is relatively simple. DXA is based on the three compartment model and separates the body into FM, lean body mass, and bone mineral density. This is done by exposing the individual to two different photonic energy levels (energy levels vary between manufacturers; Wang et al., 2010). A ratio is then derived

from the attenuation of the two different energy levels which then can be used in an equation to determine %BF.

DXA, as a body composition measurement tool, is non-invasive, valid/reliable, operator independent, and uses low doses of x-rays to complete the assessments when compared to background radiation, 2-5 μSv verses 5-7 μSv , respectively (Laskey, 1996; Madden, & Morgan, 1997). The final advantage is that this assessment tool is able to determine FM within a particular body segment (Genton, Hans, Kyle, & Pichard, 2002), as for example, there is an increase in risk of cardiovascular disease as abdominal and visceral FM increases (Svendsen, Haarbo, Hassager, & Christiansen, 1992).

Although there are several advantages to DXA, it is based on three assumptions which can limit the accuracy to which it predicts body composition. The first assumption is that there is the same amount of fat over areas where bone exists compared to bone-free areas (Genton et al., 2002), which is interesting because there are very few places in the body where measurements can be taken where bone is not present (Laskey, 1996). The second assumption is that the measurements are not affected by the anteroposterior thickness (the width of a person while lying supine) of the body. Because of a phenomenon known as beam hardening, individuals that are extremely obese (Body Mass Index (BMI) $>40\text{Kg/m}^2$) may affect the attenuation at the low and high-energy beams (Genton et al., 2002), and it has been suggested that DXA may not be suitable for individuals in excess of 300 pounds (Ratamess, 2010). The third and final assumption is that DXA assumes a constant hydrated state, between 68.2% and 78.2%, as well as, a constant electrolyte content in lean body mass (Genton et al., 2002). When hydration status is within the above range the %BF estimation is within 0.6%BF (Kelly, Berger, &

Richardson, 1998). It has been suggested that individuals in an overhydrated state may cause an increase FFM estimate. However, this argument was countered by Pietrobelli, Formica, Wang & Heymsfield (1998) who suggested that the hydration status needed to produce this error is not normally seen outside of a clinically induced status.

Near-infrared Interactance

Near-infrared interactance (NII) was originally developed to determine moisture, protein, and oil content in different grain products (Ben-Gera & Norris, 1968; Hymowitz, Dudley, Collins, & Brown 1974; Williams, Stevenson, & Irvine, 1978) and later modified to determine moisture, protein, and fat levels in raw pork and beef (Lanza, 1983). This technique was designed to replace a more time-consuming and expensive laboratory testing protocols (Lanza, 1983). This, in turn, led to the development of NII for the purposes of human body composition research (Conway, Norris, & Bodwell, 1984).

NII is based on the theory of light absorption and reflection using near-infrared spectroscopy to provide information about body composition. A light wand device is used to emit an infrared beam at a specific wave length (~945 nm; American College of Sports Medicine (ACSM), 2010). The absorption of this beam is then measured via a silicon-based detector which is expressed as two optical densities. The wand is placed over a predetermined area, specified by the manufacturer, typically between the antecubital fossa (elbow) and the axilla (armpit), and prediction equations are then used to estimate %BF using the optical densities obtained, sex, height and body weight (Ratamess, 2010).

Anthropometry

Anthropometric methods are those that use body height, weight, circumferences, and skinfolds to determine body composition (ACSM, 2010). These assessment techniques include BMI, circumference measures such as girth measurements or waist-to-hip ratio (WHR), and skinfold measurement (SFM). BMI is a simple to use measure that typically only requires a tape measure and weight scale. To calculate BMI the clinician can utilize the following equation:

$$\frac{\text{Weight (Kg)}}{\text{Height (metres)}^2} \quad (2)$$

Although easy to use, this equation does not distinguish between FM and FFM, and is typically not suited for individuals' assessment (ACSM, 2010). Furthermore, it has also been suggested that this rating scale might be inappropriate for individuals with an increased muscle mass and athletic populations (Ratamess, 2010). However, BMI can be used to determine an individual's risk for developing cardiovascular disease, type II diabetes, and hypertension (Ratamess, 2010) and is currently used in large, population-level studies to determine body composition status. When BMI is used to determine %BF the standard error of the estimate is roughly $\pm 5\%$ (Ratamess, 2010). However, when BMI is used within the athletic population, more specifically body builders, the error is higher at $\sim 7\%$ BF (van Marken Lichtenbelt, Hartgens, Vollaard, Ebbing, & Kuipers, 2004).

Similar to BMI, both the girth and WHR circumference are typically utilized to determine health risk. However, these measures can also be used to determine the distribution of adiposity as android obesity, characterised by increased fat around the

abdomen which is associated with an increased risk of hypertension, metabolic syndrome, type II diabetes, dyslipidemia and premature death (Ratamess, 2010).

Girth measurements can be used to predict body composition. Sex and age specific equations have been developed with standard errors ranging from 2.5-4%BF (Tran & Weltman, 1989). This error can be increased if improper measurement techniques are used. A deviation from the standard set forth by the International Society for the Advancement of Kinanthropometry by as little as 15 mm has been shown to cause an increase of 2% in technical error (Daniell, Olds, & Tomkinson, 2010), thus increasing the overall error of the measurement.

SFM can also be used to determine Db and %BF. The SFM assessment has two basic assumptions to determining body composition. The first assumption is that skinfold thickness at a few sites provides an adequate description of subcutaneous adipose tissue. The second assumption relies on the fixed relationship between subcutaneous adipose tissue and the adipose tissue found deeper within the body (Heymsfield et al., 2005). However, Clarys et al., (1987) assert that the actual test measures the compressibility of double layer of subcutaneous adipose tissue. Although Martin et al., (1985) determined that there was a correlation between subcutaneous fat and the deeper layers of fat in men ($r=0.75$) and women ($r= 0.89$), Clarys et al., (1984) determined that there were differences between common sites used for skinfold analysis and the compressibility of the tissue (Clarys et al., 1984). Moreover, Clarys et al. (1984) highlighted one particular comparison; two cadavers used in the study with relatively similar dissected/measured fat levels (27.1% and 27.8%) showed a 31.3%BF difference when SFM were taken (Clarys

et al., 1984). The researchers attributed this large difference to the differences in compressibility of the tissues in the different cadavers.

There are several limitations of the SFM to determine %BF. The first of which is that it often cannot be done on those individuals who are morbidly obese. The second limitation is the vast number of possible equations currently available (again, depending on sex, age, ethnicity, training status). The clinician must not only have access to these equations but must also understand the limitations of each. The final limitation is the variability of SFM taken between clinicians and the accuracy of the land marking used. However, this final concept (inter-tester reliability) will be discussed later.

Bioelectrical Impedance

Becoming commercially available in the mid 1980's (Ward, 2012), BIA uses a low level electrical current to measure body composition (e.g., BIA's rely on an estimation of TBW in order to estimate body composition rather than measuring FM directly). BIA's are currently in used in a wide range of settings (ACSM, 2010) as well as across a spectrum of ages (Lingwood et al., 2012; Patil, Patkar, Mandlik, Kuswarkar, & Jindal, 2010), weight classifications (Mattar et al., 2011), body types (Ejike & Ijeh, 2012), and disease status (Kahraman et al., 2010) due to its non-invasive nature, simplistic operation and being readily available.

A single frequency (~50 KHz) low-level current (500 mA) is used to measure whole-body impedance (Ratamess, 2010). At this frequency, the electrical current is able to pass through the cell membrane and flow through the intracellular fluid, unlike lower frequencies (<50 KHz) which can only pass through the extracellular fluid (Ratamess, 2010); thus giving a more accurate measure of TBW (intra- and extracellular fluid) and

FFM components (ACSM, 2010). The theoretical basis for BIA is that FFM is a better conductor of electricity than FM due to the increased concentration of electrolytes and water located within the muscles and surrounding tissue. Whereas FM is a poor conductor and hinders/impedes the electrical signal from reaching the intended target (Ward, 2012).

A long standing assumption is that BIA assumes that the water content of FFM is 73% (Deurenberg-Yap & Deurenberg, 2001) and the human body is a uniformly shaped cylinder (Ellis et al., 1999). Brozek et al. (1963) estimated the water content of FFM to be 73.8% compared to the *reference body*, while proteins and other minerals comprised the remaining 26.2%.

Hydrodensitometry

The term *densitometry* refers to the general estimation of body composition via Db (Heymsfield et al., 2005). The most common method of densitometry is hydrostatic weighing (HD). Densitometry is based on Archimedes' principle, which states "when a body is submerged in water it remains afloat by the counterforce equal to the weight of the water" (ACSM, 2010; Wagner & Heyward, 2001). It is this loss of weight in water that allows body volume to be calculated.

There are two approaches to determining body volume. The first of which is using a burette (i.e., a small glass cylinder with volumetric measurements along its entire length) that can be used to measure the amount of displaced water due to the subject (Allen, 1963). This displaced volume is equal to the participant's body volume (V_b). The second and most common method is underwater weighing (Heyward & Wagner 1999). This method was developed by Behnke, Feen, and Welham in 1942 and is still in

use today. Subjects are submerged underwater suspended on an underwater chair of known weight connected to either an autopsy scale or force transducers to obtain an underwater weight (Ratamess, 2010).

Very similar to air displacement plethysmography (ADP), discussed next, a measure of residual volume must be taken. Residual lung volume (RV) is the amount of air remaining in the lungs after a maximal expiration (Wilmore, 1969), and cannot be measured by spirometry (Wilmore, Costill, & Kenney, 2008). The RV measurement can be either predicted or measured. In the case of measuring RV, several techniques can be used, such as, closed-circuit oxygen, helium, and nitrogen dilution, or open circuit nitrogen *wash out* methods (Heymsfield et al. 2005; Wagner & Heyward, 2001). Error rates between predicted and measured RV have been reported to be 3.7% and 2.9% for males and females, respectively (Morrow, Jackson, Bradley, & Hartung, 1986). Moreover, Marks and Katch (1986) reported that biological variability accounted for 72% of the variability seen in RV, while 19% and 9% of total error was attributed to technical error and learning/fatigue of the participant, respectively. Furthermore, it has been suggested that RV measurements not only be utilized for research purposes but that this measurement take place underwater (Heymsfield et al., 2005). There are two possible advantages to this method. The first of which is that it removes the assumption that participants can match their maximal expiration on land, to that made underwater by removing the error associated by the compression force of the water on the body (Girandola, Wiswell, Mohler, Romero, & Barnes, 1977). Secondly, fewer trials are needed to obtain a reliable and accurate estimate (Heymsfield et al, 2005). However, no matter how much care is taken ensuring accurate measurements are taken, there will

always be error associated with HD measurement, mainly due to the error associated with measuring RV, and the theoretical error estimate has been suggested to be ~2%BF (Heymsfield et al., 2005).

Air Displacement Plethysmography

The Bod Pod, to our knowledge, is the first and the only commercially available air displacement plethysmography (ADP) system. The Bod Pod is very similar to HD in principle. Instead of using water as its medium to determine body volume (BV) it utilizes air displacement to determine BV and body density. Prior to the introduction of the Bod Pod, previous attempts were very unstable, time consuming, and highly invasive (Fields, Goran, & McCrory, 2002). For example, in Friis-Hansen's (1963) study, a plastic catheter needed to be inserted through the nasal passage, into the stomach to make a direct connection to the air inside the participants. Moreover, it was mandatory for participants to undergo 1-2 hours of calibration prior to being tested (Fields et al., 2002; Friis-Hansen, 1963).

Because this machine requires specific clothing (i.e., tight fitting and breathable) this can cause issues when %BF is estimated. For example, several studies have examined the effects of clothing on the Bod Pod's ability to estimate %BF (Hull & Fields, 2005; King et al., 2006; Shafer, Siders, Johnson, & Lukaski, 2008), yet all but one study (King et al., 2006) revealed a significant difference in %BF compared to other clothing options used within the study. A possible explanation for this could be, that King et al. (2006) used a much lighter fabric (i.e., spandex swim suit, undergarment) compared to the total amount of and heavier fabrics (i.e., cotton gym shorts, hospital gowns), and reported an underestimation of up to 8% because the warmer air (as trapped

by the heavier fabrics) is ~40% more compressible (Vescovi, Zimmerman, Miller, & Fernhall, 2002). Furthermore, the type of swim cap worn (to compress the hair against the scalp) can also have an effect on %BF estimation, both silicone and lycra caps increased %BF estimations by 4.9% and 6.1% BF, respectively, compared to not wearing a cap at 20% BF (Peeters & Classens, 2011). Finally, the presence of facial hair has been shown to significantly decrease the estimation of %BF from 17.1% to 16.2% BF (Higgins, Fields, Hunter, & Gower, 2001).

Validity and Reliability

It is important for any assessment tool to be both valid and reliable. Both reliability and validity add to the trustworthiness and quality of research. Validity is the extent to which a measurement tool assesses what it is designed to test (Thomas & Nelson, 1996). There are several different types of validity including logical, content, criterion and construct (Thomas & Nelson, 1996). Reliability refers to the acquisition of consistent results over time (Burton, Conway & Holgate 2000). Although there are several types of reliability, such as parallel forms, test-retest, internal consistency, and inter-rater or inter-observer reliability, the current literature review will only be concerned with test-retest and inter-rater reliability. Test-retest reliability or the stability of the measurement tool refers to the ability of an instrument to consistently achieve the same results at different points in time (Thomas & Nelson, 1996). This can be done on the same day, the following day, or on subsequent days, depending on what is being measured (Thomas & Nelson, 1996). Measures are considered reliable if the same results are achieved over subsequent trials without any type of intervention (Gibson, 2005). Inter-rater reliability is defined as the degree to which different testers can obtain the

same scores on the same subjects (Thomas & Nelson, 1996). Once again, assessment tools can be considered reliable if both technicians obtain similar scores while the subject remains the same. Although each body composition technique has inherent validity and reliability issues (as discussed below), having a better understanding of the limitations for each technique is an important consideration.

Validity and Reliability of DXA

DXA has been validated against both laboratory and field methods to determine total %BF. Compared to laboratory methods (i.e., HD, Bod Pod), DXA has been shown to overestimate %BF in young and elderly women, +4.5% and +2.2%, respectively, compared to HD; while both young and elderly men were underestimated +0.9 and +1.7%, respectively (Clasey et al., 1999). The difference may be due to the different assumptions (e.g., HD is based on the two-compartment model while DXA is based on the three-compartment model), thus making DXA a more specific measure of body composition.

The test-retest reliability of DXA is not well represented in the literature. However, the limited research suggests favourable results for DXA's reliability. In Leonard Roza, Barr-Orr, & Webber (2009), coefficients of variation (CV; area method to determine the variability within a sample expressed as a percentage; Lewontin, 1966) were reported for children between the ages of 4-18 years. Three consecutive tests reported CVs of 0.9% and 2.4% for FM and FFM percentages, respectively (Leonard et al., 2009). Alternatively, Hammami, Koo, & Hockman (2004) used pig cadavers of relative size to children (640 g to 21.1 kg) and reported CVs of 1.7% and 1%, for FM and FFM, respectively. Among adults, Hind, Oldtoy, and Truscott (2011) examined test-

retest reliability of the Lunar iDXA densitometer (i.e., a specific model) and reported minimal variation between test 1 and test 2 (e.g., 0.22% and 0.13% for %BF and FFM, respectively). Because there is a small amount of variation between trials one and two, DXA is a very stable measurement tool.

Although all DXA machines are based on the same basic principles, there is some variability between different devices. Tothill and colleagues (1994) examined the differences between three different devices and observed large differences of 2.6 - 6.3%BF between the three different instruments. Furthermore, Genton et al. (2002) reported differences within the software used to determine %BF to be between 0.5 - 6.9%BF. Further variation of the estimate of %BF has also been noted in Ioannidou et al. (2003), who compared two pencil-beam DXA machines to two fan-beam DXA machines and reported significant differences between one of the fan-beam methods and both pencil-beam methods (i.e., 2% and 3%, respectively; Ioannidou et al., 2003). Because of this variation between different manufacturers, models, scanning type, and equations used to determine %BF, it is difficult to accurately compare the reliability of the DXA technique within the published literature to date.

Validity and Reliability of NII

NII has been shown to be valid in female athletes between the ages of 18-27 years in an assortment of sports when compared to DXA and BIA (Fornetti, Pivarnik, Foley, & Fiechtner, 1999). However, standard error of the estimate as a percentage (SEE) was higher for NII than BIA in female athletes between the age of 18-27 years (e.g., NII = 19.3%-21.3% and BIA = 1.3% - 18%; Fornetti, et al., 1999). Body composition may influence NII, as NII has been shown to over predict %BF in obese women and youth

wrestlers by 14.7% and 1.4%, respectively (Housh, Stout, Johnson, Housh & Exkerson, 1996; Panotopoulos, Ruiz, Guy-Grand & Basdevant, 2001). Lastly, NII has similar issues to the DXA machines, in that there are several models that produce different results. Two separate studies (Housh et al., 1996; Housh et al., 2004) used similar subjects (male youth wrestlers, between the ages of 7-14) and several different NII devices and reported %BF ranges of ~11% to 26%.

Inter-rater reliability has also been assessed in NII. Schreiner Pitkaniemi, Pekkanen & Sacomaa (1995) described the inter-rater reliability of the NII system as almost approaching a significant difference as they suggested that there may be a learning curve to these types of devices but do not report data to illustrate this (Schreiner et al., 1995). Furthermore, participants did not examine themselves as trained individuals conducting the assessments, thus eliminating the examination of the untrained individual as this device was designed for personal use (Schreiner et al., 1995)

Validity and Reliability of SFM

SFM measurements have been shown to be valid against several different body composition methods. Good to excellent correlations between Bod Pod ($r=0.88$; Bentzur, Kravitz, & Lockner, 2008), ultrasound ($r=0.7$; Weits, van der Beek, & Wedel, 1996), and HD ($r=0.91-0.96$; Moon et al., 2008) have been reported. However, all of the above studies used different age- and gender-specific equations to produce %BF measurement, and different populations (i.e., athletes vs. non-athletes) thus not easily comparable across studies.

The variability of the SFM method has been largely attributed to the skill of the clinician to make appropriate measurements and the equation used (ACSM, 2010). Due to the vast number of equations that can be used to determine %BF it is difficult to make an informed decision of the reliability of this method. Several equations exist, based on age (Slaughter et al., 1988), gender (Jackson & Pollock, 1978; Jackson & Pollock, 1985), ethnicity (Heymsfield et al., 2005; Kwok, Woo, & Lau, 2000), and obesity (Heymsfield et al., 2005); however, given the large amounts of equations available, and the external factors (i.e., technical error) it is difficult to determine the overall error rate controlling for the various assumptions.

SFM measurements are further complicated by the choice of callipers used to determine skinfold thickness. Burgert and Anderson (1979) examined the difference between the McGaw and Lange callipers. Although both measures were highly correlated ($r=0.97$) and the same tester performed the measure, significant differences were found between the two sets of callipers.

Arroyo et al. (2010) investigated inter-rater reliability of SFM made by trained individuals and reported that although all measures were highly correlated ($r=0.997$), all testers reported significant differences for all three measures (i.e., upper mid-arm circumference, tricipital skinfold, and bicipital skinfold). Moreover, Yeung and Hui (2010) report internal consistency of 0.988 to 0.993 for all measures (triceps, biceps, subscapular, suprailia, thigh, and calf skinfold measures) except the abdomen. In Yeung and Hui (2010), there is no indication of the level of training which, as previously mentioned, plays an important role in the reliability of taking SFM measurements. Also, both studies use different reference points at which measurements are made. For

example, Yeung and Hui (2010) used the ACSM guidelines whereas Arroyo et al. (2010) used the guidelines set forth by the International Society for the Advancement of Kinanthropometry. Once again, deviation from the prescribed location can increase the error seen in these measures.

Validity and Reliability of BIA

The validity of single and multi-frequency impedance as a method for determining body composition remains a great topic of discussion (Lukaski, Bolonchuk, Hall, & Siders, 1986; Fornetti, et al., 1999; Heymsfield et al., 2005). This is partially due to the disproportions of the human body in terms of limbs and trunk, as well as, the size, and shape of composition of these areas (Heymsfield et al., 2005). These factors are compounded by the level of lean tissue being measured (i.e., as FFM contains more water than FM) as muscle tissue increases hydration and electrolyte levels to above average values (Heyward & Wagner, 1999). Furthermore, obese individuals (i.e., higher fat mass than normal weight individuals) have an increased ratio of extracellular to intracellular fluid (e.g., water content of FM contains roughly 14% water: 11% extracellular and 3% intracellular; Waki et al., 2001) which may decrease the accuracy of the measure (Waki et al., 2001). As the FM increases so too will the water content, and both intracellular and extracellular water. Additionally, there are several manufacturers of BIA apparatuses which use different regression equations and several different methods (foot-to-hand, leg-to-leg, and whole body impedance) to make their estimates which add to the complexity of assessing this method.

Similar to NII, BIA devices are readily available for home use, however, different manufacturers use different regression equations and different techniques (i.e., leg-to-leg,

or hand-to-hand) to make their estimates of body composition. For example, Park et al. (2010), examined the stability of measurements made by two BIA machines, and reported that both instruments were able to accurately determine body composition, when compared to each other, with the exception of mineral mass (no definition of mineral mass was given; Park et al., 2010).

Test-retest reliability was assessed in both normal and overweight females (aged 19-49 years) with no significant difference between the two trials (Demura, Sato, & Kitabayashi, 2005). However, BIA overestimated %BF for not only the whole body but also for each body segment (when compared to DXA) in both normal and overweight participants by 3.4% and 2.8%, respectively (Demura et al., 2005).

Validity and Reliability of HD

HD continues to be the criterion method of choice for body composition measurement, being compared to DXA (Bentzur, et al., 2008), ADP (Claros, Hull, & Fields, 2005; Holmes, Gibson, Cremades, & Mier, 2011), BIA (Biaggi et al., 1999) and sulphur hexafluoride dilution (Iwaoka et al., 1998), however, for the purposes of this review only ADP will be discussed as it is the closest to HD and they both use the two-compartment model. ADP and HD have been used to validate each other in both adults (Bentzur et al., 2008; Biaggi et al., 1999) and children (Holmes, et al., 2011; Claros, et al., 2005); however, the adult population will be further discussed. In the adult population, good correlations ($r=0.86 - 0.88$) have been shown between ADP and HD (Bentzur et al., 2008; Biaggi et al., 1999), which resulted in differences of 1.3%BF in males and 1.1%BF difference in females (Biaggi et al., 1999) and 3.9%BF (Bentzur et al., 2008) among female track and field athletes. The differences observed within the two

studies may be due to the populations used, as Biaggi et al. (1999) examined individuals in the general population while Bentzur et al. (2008) examined female track athletes only. Although, RV and total gas volume (TGV) were measured in both studies, Biaggi et al. (1999) measured RV while the participant was submerged in the tank up to their chin, while Bentzur et al. (2008) measured RV prior to the participant entering the tank. It has been suggested that RV measurements should be completed in the tank as it is difficult to recreate the forces of the water on the body thus giving a more accurate measure of RV (Heyward, 2001).

Several reliability studies have been conducted on HD (Akers & Buskirk, 1969; Lohman, 1992; Pollock, Hickman, Dawson, Jackson, Linnerud & Kendrick, 1976) and have all shown excellent test-retest reliability, reporting correlation values of $r > 0.95$. Slightly better results (i.e., correlation coefficients of 0.996) were observed when measures were conducted on two subsequent days (Kilduff, Lewis, Kingsley, Owen & Dietzig, 2007).

In a recent study conducted by Moon et al. (2011) examining the test-retest reliability of HD measurements by way of mechanical scale in males and females, differences were reported of 0.22 Kg and 0.1 Kg, respectively. Furthermore, van Marken Lichtenbelt et al. (2004) examined the differences between HD and a four compartment model equation, and reported a small differences between in %BF (0.01%) and FFM (0.01 Kg) compared to the four compartment model.

Inter-rater reliability has also been shown to be reliable for HD. Kohrt et al. (1992) report high correlational values of 0.98 and mean and standard deviation (SD) values for tester one and two to be $18.7 \pm 6.7\%$ and $18.7 \pm 6.4\%$, respectively. With a

small deviation reported for both testers, this suggests that both tester one and tester two were able to assess the same %BF with minimal deviation.

Once again different methods (i.e., mechanical vs. digital scale) tend to give differing results. Moon et al. (2011) compared two different methods to determine Db using load cells and a mechanical scale. Although there was no significant difference, a marginal difference was reported for both trial one and trial two of 0.22 Kg and 0.10 Kg for males and females, respectively (Moon et al., 2011). This marginal difference could be the result of an error in measurement (i.e., dry mass, underwater weight, water temperature, and/or RV). In order to estimate %BF several precise measures must be taken including dry body mass, underwater weight (within 0.20 Kg for both weight measurements), water temperature (within 0.0005 Celsius), and RV (within 100ml; Wagner & Heyward, 2001). The most critical of these measures is RV, as it accounts for a large portion of technical error when compared to that of all other measures combined (Akers & Buskirk, 1969; Wagner & Heyward, 2001).

Validity and Reliability of ADP

In addition to previous studies above, ADP has been validated against both DXA and HD. With respect to DXA, ADP has demonstrated the ability to estimate %BF in both adults and children. Ballard, Fafara & Vukovich (2004) reported no statistical difference between DXA and ADP for female athletes (i.e., $22.5 \pm 5.5\%$ BF vs. $2 \pm 4.7\%$ BF, respectively) and non-athletes (i.e., $28.5 \pm 6.7\%$ BF, $28.2 \pm 5.2\%$ BF, respectively). ADP, compared to HD, produced similar results with no significant differences reported among female non-athletes (i.e., $27.4 \pm 1.4\%$ BF and $27.1 \pm 1.3\%$ BF) and male non-athletes (i.e., $23.7 \pm 1\%$ BF and $24.4 \pm 1\%$ BF; McCrory, Gomez, Bernauer, & Mole, 1995). In the study

by McCrory et al. (1995), both TGV and RVs were measured thus decreasing the amount of error introduced, however, Ballard et al. (2004) used predicted measures of TGV thus introducing additional error into the estimation. It is thought that using predicted measures of RV (versus measured), will decrease %BF by ~1.5% (Holmes, et al., 2011; McCrory, Mole, Gomez, Dewey & Bernauer, 1998).

The reliability of ADP has been reported to be excellent in both adults ($r=0.95$) and children ($r=0.90$) when compared to HD (Demerath et al., 2002). The within-subject CVs for adults ranged from 1.7% - 4.5%BF within a single day of testing (Biaggi et al., 1999; Iwaoka et al., 1998; McCrory, et al., 1995; Miyatake, Nomaka, & Fujii, 1999; Sardinha, Lohman, Teixeira, Guedes, & Going, 1998) and from 2.0% - 2.5%BF among studies conducted between days (Fields et al., 2002; Levenhagen et al., 1999; Miyatake et al., 1999; Nunez et al., 1999). These CVs are similar to those studies using HD and DXA methodology (e.g., 1.3% - 3%; Ellis, 2001; Pierson et al., 1991; van der Ploeg, Crockett, Modra, Withers, & Gunn, 2000). However, of the studies that indicated high CV's, within a single testing day 1 (above 2.5; Miyatake et al., 1999, Sardinha et al., 1998, Iwaoka et al., 1998) a small samples was used ($n>7$). However, Noreen and Lemon (2006) used a large sample ($n=980$) to determine similar CV of 3.09%BF. Further evaluation revealed that males with a small %BF ($<10\%$ BF) had a larger CV (12.30%BF) than did males with a large %BF ($>30\%$ BF) of 1.91. Similar results were also found with females, reporting CVs of 4.14%BF and 1.48%BF for participants with less than 20%BF and greater than 40%BF, thus, indicating that the Bod Pod is more reliable in determining %BF in individuals with increase %BF.

To our knowledge, Miyatake et al. (1999) was the only study which tested subjects over a three day period and reported a CV range of 1.17-3.47% within the 10 subjects tested. Interestingly, this study also examined the inter-rater reliability of ADP, reporting a CV of 4.53% between three testers (Miyatake et al., 1999). However, upon further review of the data, as reported in a more recent review paper (Fields et al., 2002), it was discovered that the abnormally high CV was due to one unusual test and once removed, the new CV was much lower at 2.7%. Interestingly, the studies relating to the reliability of the Bod Pod have used predictive and measured TGV values. Although predicted and measured TGV values are similar (Collins & McCarthy, 2003; McCrory et al., 1998), there is still the potential for variability in TGV.

Although the Bod Pod seems to be a reliable and valid tool to measure %BF, only one study has been conducted on the reliability of the TGV measurement (Anderson, 2007). Anderson (2007) conducted two trials on three separate days (within a seven day period) using 24 healthy subjects (n=8 male, n=16 females) concluding that no significant differences between any of the TGV trials were found. However, if the participants (n=3) were unable to complete the TGV measure on the first day, a predicted value was used. Furthermore, if a participant (n=18) was unable to complete subsequent TGV measures but had successfully completed a previous measure than that value was used (Anderson, 2007). Therefore, within the one study that investigated the reliability of TGV, 75% of the participants had difficulty with the main outcome measure. Further, although there have been studies suggesting no significant differences between measured and predicted TGV values (Collins & McCarthy, 2003; McCrory et al., 1998), it is possible that the variability of TGV may influence the estimation of %BF.

Two studies have examined the relationship between HD and ADP and their ability to precisely determine Db. Both Wells, Fuller, Elia, and Dekker (2000) and Dewit, Fuller, Fewtrell, Elia, and Wells (2000) reported better precision in adult subjects (e.g., 0.11 Kg/L and 0.16 Kg/L) when compared to children (0.7 kg/L and 0.148 Kg/L) when HD is used as the criterion method. In both of the above studies, TGV was predicted rather than being measured, which may bias the results as the predicted value for TGV is more consistent compared to that provided by HD (Heymsfield et al., 2005).

Conclusion

Although all previously mentioned tools for estimating %BF have been validated and appear to be reliable, they are all based on several different assumptions and are, at best, estimates. The only conclusive way to determine true %BF is via dissection, and even that method still carries error as some tissue can be missed. When choosing a method of estimating body composition several factors should be taken into consideration. If accuracy of the measure is necessary then DXA would be the appropriate choice. If cost is a factor then BIA or SFM would be the appropriate choice. However, HD and ADP offer a good medium between cost and accuracy.

Influences on Body Composition

Gender

In terms of FFM and FM, males and females tend to develop at the same rate until approximately 12 years of age, at which time males tend to show increases in FFM while females see an increase in FM (Malina, Bouchard, & Beunen, 1988). This difference can be reflected in the adolescent growth spurt seen in males as they develop FFM and increased stature and secondary sex characteristics in females (Malina et al., 1988). Furthermore, these differences can be attributed to the sex-specific hormones, testosterone and estrogen in both males and females, respectively (Wilmore et al., 2008). Testosterone has been attributed to the development of bones and protein synthesis, leading to the increased muscularity in males. Moreover, estrogen has been linked to the development of secondary sex-characteristics such as breast tissue development, as well as, an increase FM deposits around the hips and thighs (Wilmore et al., 2008). Malina et al. (2004) suggests that for every centimetre of growth in both males and females there is an accumulation of roughly 0.36 and 0.26 Kg of FFM, respectively, which plateaus roughly at 20 years of age. This trend coincides with the termination of the growth phase. Further changes to body composition as they related to the aging process have been attributed, in part, to the decline of resting metabolic rate (RMR; Fukagawa, Bandini & Young, 1990). RMR is the rate at which the body uses energy (Wilmore et al., 2008) and accounts for ~50-75% of the body's total energy expenditure (Fukagawa et al., 1990) and decline ~1-2% a year after the age of 20 (Keys, Taylor, & Grande, 1973). If this decline in RMR is not accounted for via lifestyle changes (i.e., exercise, diet), it

can lead to an energy imbalance (discussed later) thus leading to an increase need to store excess energy as fat.

Clarys, Martin & Drinkwater (1984) illustrated the similarities between distribution sites of FM of males and females. When considering FM in the trunk, males tend to have more internal or visceral FM while females tend to have more subcutaneous FM. Further, males tend to accumulate more fat in the lower extremities, compared to females (i.e., 20.48% vs. 22.02%; Clarys et al., 1984). The accumulation of visceral fat has been shown to be a predictor of several metabolic disorders including impaired glucose tolerance (Srinivasan, Wang, Chen, Wei, Xu, & Berenson, 2009), insulin resistance (Kim, Valentine, Shin, & Gong, 2008) dyslipidemia (Pascot et al., 1999), type 2 diabetes (Boyko, Fuimoto, Leonetti, & Newell-Morris, 2000), hypertension (Rheume et al., 2009), and metabolism syndrome (Desprea & Lemieux, 2006), all of which are associated with an increased risk of developing cardiovascular diseases (Li, Katashima, Yasumasu, & Li, 2012).

Physical activity

Physical activity (PA) has been defined as any movement made by skeletal muscle which results in a substantial increase over resting energy expenditure, while exercise is a type of PA which is planned, structured and repetitive in nature (Caspersen, Powell, Christenson, 1985; ACSM, 2011). It is generally accepted that exercise can have noteworthy effects on body composition, specifically FFM and FM (Forbes, 1991). This is, in part, due to the positive/negative energy balance within the body. With the introduction/increase in PA with no alteration of diet, this places the body in a negative energy balance. This means that the amount of calories needed to sustain the individual's

current weight is not sufficient and, therefore, the body must use fat stores (as well as other sources) for energy (Thompson, Karpe, Lafontan, & Frayn, 2012) thus potentially decreasing %BF. Several studies have been conducted to support the notion that PA can lead to body composition changes (Giannopoulou et al., 2005; Howe, Harris, & Gutin, 2011; Janssen et al., 2002; Ross et al., 2000). However, within these studies there is typically some form of dietary restriction, which places the body further into a caloric deficit and increases the effects of exercise. For example, Janssen et al. (2002) asked participants to reduce their caloric intake by 1,000 calories from their individual daily energy requirements, while Ross and colleagues (2000) asked participants to reduce their caloric intake by 700 calories a day.

However, there is some evidence to suggest that PA itself can affect body composition (Giannopoulou et al., 2005; Howe, et al., 2011; Lara, Casanova, & Spritzer, 2010; Ross et al., 2000). In a study by Howe et al. (2011), the relationship between PA and body composition in 106 African American boys aged 8-12 years was examined. Those who attended the structured exercise program ($\geq 60\%$ of sessions) reported a significant decrease in %BF of 2.3%, whereas the non-attenders group ($< 60\%$ of the sessions) lost only 1.4%BF. Attenders and non-attenders also gained 3.1 Kg and 3.3 Kg of FFM, respectively. Furthermore, Lara et al. (2010) noted similar results (i.e., decrease in FM) in elderly women undergoing hormone replacement therapy, however, there was no significant decrease in FM. This can be a product of the increased intensity of the PA protocol in Howe et al. (2011) as these participants were asked to participate in a strict PA regiment which occurred almost daily, while Lara et al. (2010) only asked participants to walk $> 6,000$ steps to be considered active. Further variation can be seen

in the studies methods of estimating %BF, as Howe et al. (2011) used DXA while Lara et al. (2010) used both skinfold and girth measurements to make the body composition estimates. Exercise, in and of itself, can alter one's body composition. However, with the addition of diet change (i.e., decreasing caloric intake) these effects can be increased. In the previously mentioned articles, diet was not controlled for so it is feasible that some of the results seen could have been due to a diet change. To date there has been no data reported on the Bod Pod's ability to estimate %BF after an acute bout of exercise.

Hydration

As water constitutes the largest part of the human body, it is only reasonable to assume that when hydration levels change so too will body composition. It is generally assumed that the FFM contains between 71.8% to 73.8% water in most populations (Lohman, 1986). Among younger individuals (12-18 years of age) Heald et al. (1963) reported an increase in hydration of FFM with the increase in age. Although hydration status changes with age, water content still has an effect on body composition assessments. Utter et al. (2003) found that a decrease in hydration of 2-3% resulted in a decrease in total body mass of 2 Kg or 2.6% body weight. Furthermore, Vukovich and Peeters (2003) reported significant differences when water was added to the body. With the addition of just 500 mL, body mass and Db increased by 0.49 Kg and 0.52 L, respectively. Further, significant increases in %BF from baseline measures were observed with the increased water intake of 2.33%BF with the final intake of 2,000 mL (Vukovich & Peeters, 2003). Although these studies view different spectrum of hydration (decrease vs. increase) both demonstrated the effects of water on body composition.

Food/last meal

Although there has been some research conducted on the effects of food intake on the human body (Bojanowska & Radziszewska, 2011; Yu, Geary, & Corwin, 2011) as well as over consumption and evening snacking (Corbalan-Tutau, Madrid, & Garaulet, 2012; Kong et al., 2011; Waller et al., 2004), there is currently no data available on acute meal consumption and body composition or body mass testing. Conventional thought would suggest that the amount of food consumed would add to the individuals overall mass, however, this cannot be known for certain without sufficient data. In order to standardize between body composition measurement techniques, the general rule of thumb is to not consume anything (i.e., food) for two hours prior to any testing.

Clothing

Although perhaps quite obvious, very limited research has been conducted on the effect of clothing on body mass (i.e., besides clothing worn in the bod pod and its effect on body density). Whigham, Schoeller, Johnson & Atkinson (2012) recently determined that clothing added an additional 1.2 Kg and 0.8 Kg of weight to both males and females, respectively. There was no mention on clothing type or actual weight of clothing. However, once again conventional thought would dictate that, with the addition of clothing there would be an increase in overall mass.

Implication for current research

As outlined above, there are several factors that can influence body composition. It is important when considering body composition testing that these factors be controlled or a standardized protocol be used to limit the amount of error being introduced into the measurement. For example, in the current research study, items such as training status, clothing (worn in the Bod Pod), and hydration status will all be accounted for. In respect to training status, individuals who are current exercisers have a greater ability to adapt to the physiological stresses that are caused by exercise (Wilmore et al., 2008) and thus will form a more homogeneous sample for the current study.

Accounting for hydration status is also important. As previously mentioned, both spectrums of hydration (dehydration vs. hydrated) can effect body composition. Since trained individuals are able to respond more efficiently to bouts of PA (e.g., better ability to thermoregulate), standardised amounts of water should be given to individuals after exercise to replenish water lost due to perspiration.

Finally, as previously discussed, clothing can influence body composition. Standardized protocols should be used to ensure congruency between different testing times to ensure similarities. For example, in this study, individuals will be asked to change in between the baseline measures and exercise session and then back into their original attire. This will ensure that sweat will not accumulate in the clothes, potentially affecting the accuracy of the body composition measure by potentially altering the BV of the participant.

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Appendix A

Demographic, Health, and Physical Activity Questionnaire

Name: _____

Age: _____

Height: _____ Weight: _____ BMI: _____

Sex: _____

Participant I.D. # _____

For office use onlyHeart rate: $75\% = 220 - \text{age} \times 0.64 =$ _____**Contact Information:**

E-mail: _____ @ _____

Emergency Contact (Optional)

Name: _____

Phone #: () _____ - _____

Physical Activity Background:

Have you ever been a member of a varsity sports team? Yes / No

If yes, how many years has it been since you actively participated _____ years

Mark how many minutes of physical activity you did on each of the past 7 days. Include physical activity during sports, lunch, evenings, and spare time. Physical activities include skating, bike riding, running, rollerblading, and any other physical activities that cause you to sweat and to breathe harder or “be out of breath”.

	None	1-15 minute	16-30 minutes	31-59 minutes	1-2 hours	More than 2hr
Monday	☐	☐	☐	☐	☐	☐
Tuesday	☐	☐	☐	☐	☐	☐
Wednesday	☐	☐	☐	☐	☐	☐
Thursday	☐	☐	☐	☐	☐	☐
Friday	☐	☐	☐	☐	☐	☐
Saturday	☐	☐	☐	☐	☐	☐
Sunday	☐	☐	☐	☐	☐	☐

For females:

What was the first day of your last menstrual cycle? _____

Have you experienced irregular menstruation over the past 2 years? _____

Are you currently taking oral contraceptives (e.g., birth control pills)? YES/NO

Appendix B

Physical Activity Readiness Questionnaire

Physical Activity Readiness
Questionnaire - PAR-Q
(revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO	
☐	☐	1. Has your doctor ever said that you have a heart condition <u>and</u> that you should only do physical activity recommended by a doctor?
☐	☐	2. Do you feel pain in your chest when you do physical activity?
☐	☐	3. In the past month, have you had chest pain when you were not doing physical activity?
☐	☐	4. Do you lose your balance because of dizziness or do you ever lose consciousness?
☐	☐	5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?
☐	☐	6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
☐	☐	7. Do you know of <u>any other reason</u> why you should not do physical activity?

If
you
answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

- If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:
- start becoming much more physically active — begin slowly and build up gradually. This is the safest and easiest way to go.
 - take part in a fitness appraisal — this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever — wait until you feel better; or
- if you are or may be pregnant — talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME _____

SIGNATURE _____

DATE _____

SIGNATURE OF PARENT
or GUARDIAN (for participants under the age of majority) _____

WITNESS _____

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

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