Short-Term Precision Error of Body Composition Assessment Methods in Resistance-Trained Male Athletes

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Athletic populations require high-precision body composition assessments to identify true change. Least significant change determines technical error via same-day consecutive tests but does not integrate biological variation, which is more relevant for longitudinal monitoring. The aim of this study was to assess biological variation using least significant change measures from body composition methods used on athletes, including surface anthropometry (SA), air displacement plethysmography (BOD POD), dual-energy X-ray absorptiometry (DXA), and bioelectrical impedance spectroscopy (BIS). Thirty-two athletic males (age = 31 ± 7 years; stature = 183 ± 7 cm; mass = 92 ± 10 kg) underwent three testing sessions over 2 days using four methods. Least significant change values were calculated from differences in Day 1 Test 1 versus Day 1 Test 2 (same-day precision), as well as Day 1 Test 1 versus Day 2 (consecutive-day precision). There was high agreement between same-day and consecutive-day fat mass and fat-free mass measurements for all methods. Consecutive-day precision error in comparison with the same-day precision error was 50% higher for fat mass estimates from BIS (3,607 vs. 2,331 g), 25% higher from BOD POD (1,943 vs. 1,448 g) and DXA (1,615 vs. 1,204 g), but negligible from SA (442 vs. 586 g). Consecutive-day precision error for fat-free mass was 50% higher from BIS (3,966 vs. 2,276 g) and SA (1,159 vs. 568 g) and 25% higher from BOD POD (1,894 vs. 1,450 g) and DXA (1,967 vs. 1,461 g) than the same-day precision error. Precision error in consecutive-day analysis considers both technical error and biological variation, enhancing the identification of small, yet significant changes in body composition of resistance-trained male athletes. Given that change in physique is likely to be small in this population, the use of DXA, BOD POD, or SA is recommended.

Keywords: anthropometry, bioelectrical impedance spectroscopy, BOD POD, dual-energy X-ray absorptiometry, fat-free mass, fat mass, least significant change

The association between athletic physique traits and competitive sporting success is well established (Meyer et al., 2013; Olds, 2001). In sports requiring high-force production, athletes with high levels of muscularity can gain a competitive advantage (Bilsborough et al., 2016; Gabbett, 2009; Olds, 2001), yet these athletes tend to see only small adaptations or improvements in physique over time (Binkley et al., 2015; Harley et al., 2011; Lees et al., 2017; Smart et al., 2013). Given this evidence, assessment methods with high precision are required to measure body composition on a regular basis in these athletes. By accurately quantifying changes in physique, more refined training and dietary interventions may be implemented, which can positively influence performance outcomes (Slater et al., 2005).

A variety of body composition assessment methods are available to quantify fat-free mass (FFM) and fat mass (FM) (Ackland et al., 2012; Kerr et al., 2017). Depending on time and resources, the four most popular methods used on athletic populations are air displacement plethysmography (BOD POD), dual-energy X-ray absorptiometry (DXA), bioelectrical impedance spectroscopy (BIS), and surface anthropometry (SA) (Meyer et al., 2013). Despite differences in technology, resources, and technical expertise required, they are all susceptible to technical error and

biological variation (Ackland et al., 2012; Meyer et al., 2013), which significantly affects precision (Kerr et al., 2017; Kerr et al., 2018). Technical error is influenced by quality control procedures, such as subject clothing (Fields et al., 2000; Vescovi et al., 2002), and positioning during assessment (Kerr et al., 2016; Lambrinoudaki et al., 1998; Tegenkamp et al., 2011), level of technical expertise (Hume & Marfell-Jones, 2008; Ruiz et al., 1971), and equipment calibration (Marfell-Jones et al., 2012). Biological variation may result from food and fluid ingestion or exercise prior to assessment and appears to influence most body composition methods, albeit to different degrees (Bone et al., 2017; Kerr et al., 2017). Other biological variables known to have an impact on estimates of body composition include body temperature and skin moisture (Fields et al., 2004), gastrointestinal contents (Bone et al., 2017), and muscle solutes (Rouillier et al., 2015).

While quantification of precision error (PE) is frequently done by calculating differences in same-day repeat assessments of body composition (Hangartner et al., 2013; Hind et al., 2018) using least significant change (LSC) values, this fails to account for biological variability in the absence of controls, and can be evident during longitudinal monitoring (Meyer et al., 2013). Given this evidence, we have advocated for identifying the LSC for same-day (technical error) and consecutive-day (biological variation) precision in estimates of FM and FFM, finding a more accurate interpretation of true and meaningful change (Zemski et al., 2019). Currently, the precision of BOD POD, BIS, and SA, using LSC values for same-day and consecutive-day analysis, has not been explored. Therefore, the aims of this study were to (a) establish the same-day

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technical error of the four methods and (b) determine the consecutive-day PE of the methods using LSC values to determine the threshold of meaningful change in resistance-trained male athletes.

Methods

Subjects

Thirty-two White volunteers participated in this study and met the inclusion criteria, which included being male, having at least ≥ 2 years resistance training experience, and having a body mass index of ≥ 25 . Subjects were excluded from the study if they were > 190 cm tall due to the limitation of the active scanning area of the DXA bed. The characteristics of all individuals are presented in Table 1. All subjects were informed of the nature and possible risks of the investigation before giving their written informed consent. This study was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures involving subjects were approved by the human research ethics committee of the University of the Sunshine Coast (ethics approval no. S/12/450).

Experimental Design

Each subject underwent three testing sessions during a 24-hr window over a 2-day period (Figure 1), with each measurement taken by the same technician. The sessions commenced with body mass and stretch stature measured in minimal clothing, a total body DXA scan immediately followed by a BIS estimation of total body water (TBW), a BOD POD test, and an assessment of subcutaneous FM via the skinfold technique, in that sequence. Each subject undertook Tests 1 (D1T1) and 2 (D1T2) on Day 1 under standardized conditions (early morning, overnight fasted, well rested, and bladder voided). D1T2 was undertaken immediately after D1T1,

and Test 3 (D2) was undertaken the following morning, 24 hr after D1T1. Comparison of these testing sessions allowed for the calculation of typical error of measurement, random consecutive-day biological variability, and the difference in estimates of body composition data.

Subject Presentation

Guidance was provided on both days to encourage adherence to the standardized presentation for all three of the tests (D1T1, D1T2, and D2), as per current best practice guidance (Fields et al., 2004; Hind et al., 2018; Hume et al., 2018; Kyle et al., 2004). Subjects were required to present overnight fasted, bladder voided, and well rested (no prior physical activity) on the mornings before D1T1 and D2. They were asked to wear minimal fitted clothing, with metal objects and jewelry removed, plus the clothing was checked for metal zips or studs. Hydration status was assessed by a midstream sample of urine provided by the subjects early on both mornings before testing (D1T1 and D2). The specific gravity of the urine sample was measured using a digital refractometer (UG-Alpha; Atago Corporation, Tokyo, Japan). All subjects voided their bladder before tests.

Dual-Energy X-Ray Absorptiometry

All DXA scans were undertaken in the total body mode on a pencil beam DXA scanner (Lunar DPX; GE Healthcare, Madison, WI), with analysis performed using GE enCORE software (version 13.60; GE Healthcare) with the combined Geelong/Lunar reference database. Coefficient of variation (CV) measurements for the laboratory being 0.1%, 2.2%, 0.6%, and 1.0% for BM, FM, lean mass, and bone mineral content, respectively. The DXA was calibrated with phantoms, as per the manufacturer's

Table 1 Descriptive Statistics for Body Composition Variables

Variable	Day 1		Day 2	
	<i>n</i> = 32	Range	<i>n</i> = 32	Range
Age (years)	31 $\pm$ 7	18–47		
Stature (cm)	182.5 $\pm$ 7	168.7–190.0		
Mass (kg)	91.5 $\pm$ 10.1	75.1–114.5	91.5 $\pm$ 10.1	75.1–113.9
BMI (kg/m ²)	27 $\pm$ 3	25–33		
USG	1.019 $\pm$ 0.007	1.002–1.028	1.019 $\pm$ 0.007	1.002–1.029
BMC (kg)	3.84 $\pm$ 0.42	2.89–4.67	3.84 $\pm$ 0.42	2.91–4.67
TBW (kg)	57.3 $\pm$ 5.8	47.1–71.1	57.1 $\pm$ 6.1	47.0–71.4
Skinfolds sum of 8 (mm)	82 $\pm$ 30	36–172	81 $\pm$ 30	36–171
FM (kg)				
BOD POD	16.8 $\pm$ 6.4	6.4–32.0	16.6 $\pm$ 6.3	6.5–31.3
BIS	13.3 $\pm$ 7.2	1.1–31.0	13.4 $\pm$ 6.6	2.0–30.9
DXA	17.1 $\pm$ 6.9	5.0–33.4	16.8 $\pm$ 6.6	5.8–32.3
SA	11.0 $\pm$ 4.2	5.2–22.9	10.9 $\pm$ 4.1	5.1–22.5
FFM (kg)				
BOD POD	74.8 $\pm$ 7.5	60.7–90.0	75.0 $\pm$ 7.5	61.7–91.0
BIS	78.2 $\pm$ 7.9	64.4–97.1	78.1 $\pm$ 8.3	64.2–97.6
DXA	74.7 $\pm$ 7.6	60.0–91.3	74.9 $\pm$ 7.8	59.8–93.0
SA	80.6 $\pm$ 8.2	68.4–102.5	80.7 $\pm$ 8.2	68.3–102.1

Note. Values are presented as mean $\pm$ SD. BMI = body mass index; USG = urine specific gravity; BMC = bone mineral content; TBW = total body water; BOD POD = air displacement plethysmography; BIS = bioelectrical impedance spectroscopy; DXA = dual-energy X-ray absorptiometry; SA = surface anthropometry; FM = fat mass; FFM = fat-free mass.

Figure 1 — Study design of three testing sessions conducted over 24 hr.

guidelines, each day before the measurements were taken. All scans were conducted by the same Queensland Radiation Health licensed technician, using the standard thickness mode as determined by the auto scan feature in the software, and all safety protocols were adhered to as per the University of the Sunshine Coast Radiation Safety Protection Plan. The scans were performed according to a protocol developed that emphasized a consistent positioning of subjects on the DXA scanning bed (Nana et al., 2012a), as previously described (Nana et al., 2012b). In addition, two Velcro straps were used to minimize any subject movement during the scan as well as to provide a consistent body position for subsequent scans. One strap was secured around the ankles above the foot positioning pad, and the other strap was secured around the trunk at the level of the mid forearms (Kerr et al., 2016). All scans were analyzed automatically by the DXA software, but all regions of interest were reconfirmed before being included in the subsequent statistical analysis.

Bioelectrical Impedance Spectroscopy

Immediately after each DXA scan, while the subjects were still positioned on the DXA scanning bed, body composition, derived from TBW obtained values, was measured using the SFB7 BIS device (ImpediMed Ltd., Brisbane, Queensland, Australia). Subject positioning was standardized (Kyle et al., 2004) to ensure supine positioning on the nonconductive foam mattress without contact to the metal side supports of the DXA scanner for a minimum of 15 min before BIS measurements (Ward et al., 2015). The BIS was calibrated as per the manufacturer's instructions, with each participant's stature, body mass, age, and sex programmed into the unit. Sites of attachment for the electrodes (ImpediMed) were first shaved and cleaned with alcohol wipes before the dual-tab electrodes were attached as follows: one electrode was attached centrally on the top side of the wrist in alignment with the ulnar head and 5 cm lower on

the dorsal surface of the hand. The second electrode was attached centrally on the dorsal surface of the ankle between the lateral and medial malleoli and 5 cm lower on the dorsal surface of the foot, which is in accordance with previous guidelines (Kerr et al., 2015). The SFB7 measures impedance using 256 frequencies between 4 and 1024 kHz to estimate TBW based on a Cole–Cole plot (Cornish et al., 1996). Three measurements were taken consecutively, and the median of these used in subsequent analysis. The TBW value, as per the Pace et al. model (Pace & Rathbun, 1945), was used to estimate body composition of FFM and FM by simple subtraction from body mass.

Air Displacement Plethysmography

Immediately after BIS measurement, assessment of body density was undertaken using the BOD POD (life measurement instruments) following the recommended procedures of the manufacturer (Dempster & Aitkens, 1995), utilizing a validated, predicted thoracic lung volume estimation (McCrory et al., 1998). Subjects wore Lycra clothing and a silicone swim cap, with all metal objects removed before measurement. Body density was calculated by the BOD POD's software system (version 5.3.2; COSMED, Concord, CA) as follows:

$$D(\text{density})\text{Mass}(\text{scale}) = \text{Volume}(\text{BOD POD}).$$

An estimate of FM and FFM was obtained to calculate %BF, as defined by the Siri equation (Siri, 1961), as follows:

$$\%BF = (497.1/\text{body density}) - 451.9.$$

Surface Anthropometry

Immediately after completion of the BOD POD assessment, duplicate skinfold measurements were taken, according the International Society of the Advancement of Kinanthropometry technique, by

Table 2 Mean Difference ($\pm$ SD) Between Same-Day Tests (Technical Error) and Consecutive-Day Tests (Technical Error and Biological Variation)

<i>n</i> = 32	Same day	Consecutive day
	D1T1/D1T2	D1T1/D2
FM (g)		
BIS	676 $\pm$ 698	1,132 $\pm$ 988
BOD POD	483 $\pm$ 360	642 $\pm$ 492
DXA	376 $\pm$ 332	520 $\pm$ 426
SA	174 $\pm$ 171	147 $\pm$ 110
FFM (g)		
BIS	663 $\pm$ 679	1,234 $\pm$ 1097
BOD POD	478 $\pm$ 368	620 $\pm$ 487
DXA	493 $\pm$ 355	587 $\pm$ 572
SA	168 $\pm$ 167	381 $\pm$ 295

Note. Values are presented as mean $\pm$ SD. D1T1 = Day 1 Test 1; D1T2 = Day 1 Test 2; D2 = Day 2 Test 1; FM = fat mass; FFM = fat-free mass; BOD POD = air displacement plethysmography; BIS = bioelectrical impedance spectroscopy; DXA = dual-energy X-ray absorptiometry; SA = surface anthropometry.

Figure 2 — LSC for DXA, BOD POD, BIS, and SA for same-day and consecutive-day measures. BOD POD = air displacement plethysmography; BIS = bioelectrical impedance spectroscopy; DXA = dual-energy X-ray absorptiometry; SA = surface anthropometry; LSC = least significant change.

the same technician certified by the International Society of the Advancement of Kinanthropometry, as previously described (Norton et al., 1996).

The sum of eight skinfolds was determined following measurements of the triceps, biceps, subscapular, iliac crest, supraspinale, abdominal, quadriceps, and calf skinfolds using a

Table 3 Precision Error for Each Method, Represented as the %CV, With the RMS-SD, LSC, and %LSC

Method	RMS-SD	LSC-95% CI	% CV	%LSC-95% CI
D1T1/D1T2 technical error				
FM (g)				
BIS	842	2,331	5.2	14.4
BOD POD	523	1,448	2.5	6.9
DXA	435	1,204	1.5	4.2
SA	212	586	1.0	2.9
FFM (g)				
BIS	822	2,276	0.6	1.6
BOD POD	524	1,450	0.5	1.3
DXA	528	1,461	0.5	1.3
SA	205	568	0.2	0.4
D1T1/D2 technical error and biological variation				
FM (g)				
BIS	1,302	3,607	9.4	25.9
BOD POD	702	1,943	2.8	7.8
DXA	583	1,615	2.4	6.6
SA	160	442	1.0	2.7
FFM (g)				
BIS	1,432	3,966	1.1	3.1
BOD POD	684	1,894	0.6	1.7
DXA	710	1,967	0.5	1.5
SA	418	1,159	0.3	0.9

Note. D1T1 = Day 1 Test 1; D1T2 = Day 1 Test 2; D2 = Day 2 Test 1; RMS-SD = root mean square SD; LSC = least significant change; CV = coefficient of variation; CI = confidence interval; BIS = bioelectrical impedance spectroscopy; BOD POD = air displacement plethysmography; DXA = dual-energy X-ray absorptiometry; SA = surface anthropometry; FM = fat mass; FFM = fat-free mass.

calibrated skinfold caliper (Harpender; Bate International, Burgess Hill, United Kingdom). Due to the similar procedure, equipment, and population used, the 4C validated Evans equation of three skinfolds (triceps, abdominal, and thigh) was utilized to calculate %BF as (Evans et al., 2005):

$$\%BF = 8.997 + 0.24658 \times (3SKF) - 6.343 \times (\text{gender}) - 1.998 \times (\text{race}),$$

Gender coded as 0 = female, 1 = male, and ethnicity coded as 0 = White, 1 = Black.

Stretch stature was measured with a stadiometer (Harpender; Holtain Ltd., Crymch, United Kingdom) to the nearest 0.1 cm. Body mass was measured on a calibrated scale to the nearest 0.01 kg (Seca GmbH, Hamburg, Germany).

Statistical Analysis

Data analysis was performed using Microsoft Excel (Microsoft, Redmond, WA). Descriptive data are reported as the mean $\pm$ SD. The precision is reported as the root mean square SD and %CV. The resulting LSC with 95% confidence intervals was calculated following the International Society for Clinical Densitometry (ISCD) protocol (Hangartner et al., 2013). The %CV was derived from the equation $\%CV = (SD/\text{mean}) \times 100$. Coefficients of determination (R^2) were calculated for measurements to establish the relationship

Figure 3 — Regression analysis between measures of FM for same-day precision. FM indicates fat mass.

Figure 4 — Regression analysis between measures of FM for consecutive-day precision. FM indicates fat mass.

between same-day and consecutive-day measures. A one-way analysis of variance was used to determine if there was an effect of time on FM and FFM for each method. Statistical significance was set at .05. Bland–Altman plots were created to compare individual same-day and consecutive-day precision for all techniques.

Results

Descriptive statistics for the participants in this study are given in Table 1. The analysis of variance showed there was no effect of time on FM, $F(2, 93) = 0.01\text{--}0.03$, $p > .97$, and FFM, $F(2, 93) = 0.01\text{--}0.02$, $p > .99$, for each method. The mean differences between same-day (technical error) and consecutive-day (technical error and biological variation) testing for FM and FFM in all methods are shown in Table 2. Differences between same-day and consecutive-day testing, demonstrating the LSC values for all methods, are given in Figure 2.

Table 3 shows the PE for each method of testing, represented as the %CV, with the root mean square SD, LSC, and %LSC. Strong agreement was found for all methods for same-day and for consecutive-day FM regression analysis (SA $R^2 = 1.00\text{--}1.00$, BOD POD $R^2 = .99\text{--}.99$, DXA $R^2 = 1.00\text{--}.99$, BIS $R^2 = .98\text{--}.96$), as shown in Figures 3 and 4. Regression analysis undertaken for same-day and consecutive-day FFM for all methods revealed strong relationships (SA $R^2 = 1.00\text{--}1.00$, BOD POD $R^2 = .99\text{--}.99$, DXA $R^2 = .99\text{--}.99$, BIS $R^2 = .99\text{--}.96$), as shown in Figures 5 and 6.

Bland–Altman analysis revealed that SA had the smallest level of bias between same-day and consecutive-day precision for FM (83 g) and FFM (178 g), with very low limits of agreement (FM =

–7 to 173 g; FFM = –185 to 172 g). DXA and BOD POD had low levels of bias between same-day and consecutive-day precision for FM (DXA = 226 g; BOD POD = 318 g) and FFM (DXA = 309 g; BOD POD = 321 g), with low limits of agreement for DXA (FM = –365 to 87 g; FFM = –59 to 558 g) and BOD POD (FM = –275 to 361 g; FFM = –251 to 390 g). The largest level of bias between same-day and consecutive-day precision came from BIS for FM (524 g) and FFM (580 g), with wider limits of agreement (FM = –108 to 939 g; FFM = –930 to 230 g), as shown in Figures 7 and 8.

Discussion

To our knowledge, this is the first study exploring both technical error and the short-term biological variation within a 24-hr period, using four independent methods of body composition assessment. The body composition PE was greater when quantified from consecutive-day compared with same-day results on a resistance-trained athletic male cohort. This was evident across all body composition assessment techniques. Consecutive-day PE was 25% higher for DXA and BOD POD (FM and FFM) estimations and nearly 50% higher for BIS (FM and FFM) and SA (FFM) than same-day PE. It must be noted that same-day and consecutive-day PE in SA (FFM) were lower than all other methods. In contrast, the SA FM PE for same-day and consecutive-day analysis was lower for consecutive day, but only by 8%, and was not significantly different ($p < .5$). This shows that biological variation affects measurement precision even within very short time frames (24 hr), at least when using BIS, DXA, and BOD POD methodology. Therefore, the use of consecutive-day PE is advocated as

Figure 5 — Regression analysis between measures of FFM for same-day precision. FFM indicates fat-free mass.

Figure 6 — Regression analysis between measures of FFM for consecutive-day precision. FFM indicates fat-free mass.

longitudinal monitoring of physique and will always include both technical error and biological variation.

Excellent SA same-day precision was found for estimations of FM (CV 1.0%) and FFM (CV 0.2%), as well as for consecutive-day testing with FM (CV 1.0%) and FFM (CV 0.3%), respectively. Raw measurements from SA (in millimeters) have been shown to be robust and unaffected by the biological variation caused by prior food and fluid ingestion or exercise (Kerr et al., 2017), yet this study included body mass to obtain estimates of FM and FFM using the Evans equation (Evans et al., 2005). It would be expected, then, that consecutive-day PE would be larger given that body mass is acutely influenced by hydration status, gastrointestinal tract contents, and muscle glycogen stores (Rouillier et al., 2015). Due to adopting previous recommendations of subject presentation, including overnight fasting, post bladder, and bowel evacuation with body measurements taken early in the morning in minimal clothing, the biological impact on precision was expected to be minimal (Kerr et al., 2017; Nana et al., 2015).

The DXA is prone to biological variance due to changes in hydration, significantly affecting FFM estimates (Kerr et al., 2017). This is particularly noticeable in large muscular males with high levels of FFM (Barlow et al., 2015; Bilsborough et al., 2014). Previous literature and manufacturing guidance suggest that a standardized testing protocol be adopted to minimize technical error and biological variation (Kerr et al., 2016; Nana et al., 2012a). This is in agreement with previously reported results, a CV of 0.5% and 1.5%, respectively (De Lorenzo et al., 1997; Nana et al.,

2012a), and more recently, results from Zemski et al. (2019), with a consecutive-day FM CV of 2.9% and lean mass CV of 1.1%. Despite obtaining excellent precision from utilizing a standardized presentation protocol, those authors found biological variance (consecutive day) to be higher than technical error (same day), most probably due to short-term changes in hydration (Nana et al., 2012a), sleep hygiene (Vitale et al., 2019), and intramuscular solute levels (Bone et al., 2017). These findings would support the results from this study with an FM and FFM CV of 2.4% and 0.5%, respectively. While current best practice guidance was followed, this may not account for variance in muscle solute content, which is known to influence reliability. The impact of standardized training and diet on consecutive-day precision warrants investigation.

Close comparisons between DXA and BOD POD were identified in this study, with strong agreement found in same-day and consecutive-day FM PE (BOD POD $R^2 = .99-.99$, DXA $R^2 = 1.00-.99$) and FFM (BOD POD $R^2 = .99-.99$, DXA $R^2 = .99-.99$). In support, previous research using DXA and BOD POD technology shows consistent results with this study, with only small or trivial PE in FM and FFM estimates from consecutive-day testing conducted under standardized presentation conditions (Kerr et al., 2017). Despite BOD POD estimates of FM, and FFM being subject to biological variation if unrestricted subject presentation occurs (food and fluid intake plus physical activity), BOD POD precision in this study showed that very high resolution can be obtained if these variables are controlled (FM CV 2.8%, FFM CV 0.6%). A

Figure 7 — Bland–Altman plots for differences in same-day versus consecutive-day measures for FM. FM indicates fat mass; BOD POD = air displacement plethysmography; BIS = bioelectrical impedance spectroscopy; DXA = dual-energy X-ray absorptiometry; SA = surface anthropometry.

limitation of this study is that the DXA scanner used to estimate body composition (GE Lunar DPX Pro) has been superseded by newer models with enhanced precision. PE from the DPX estimations has been found to be twice as high as the GE Lunar Prodigy in athletes (Bilsborough et al., 2014), whereas the iDXA model resolution has improved bone edge detection, thus allowing for superior algorithms for body composition estimation (Toombs et al., 2011).

Factors that impact TBW, such as prior food and fluid intake, physical activity, or medical conditions, make BIS vulnerable to imprecision (Kyle et al., 2004). Additionally, variance in fluid and electrolyte content will affect TBW (Saunders et al., 1998) and

confound any change in physique traits inferred from BIS (O'Brien et al., 2002). Given normal daily fluctuations in TBW, it is unsurprising that the change between same-day and consecutive-day precision using BIS derived estimates of FM and FFM showed nearly a 50% increase in PE for both FM (3,607 vs. 2,331 g) and FFM (3,966 g vs. 2,276 g) estimates. BIS also had the highest CV% of all methods for both same-day FM and FFM (5.2% and 0.6%) and consecutive-day values (9.4% and 1.1%), respectively. This suggests that despite implementing a rigorous athlete presentation protocol prior to testing, a lower tolerance level for precision still occurs. Given this evidence, the ability of BIS to accurately track small changes in the physique among athletic populations is questionable.

Figure 8 — Bland–Altman plots for differences in same-day versus consecutive-day measures for FFM. FFM indicates fat-free mass; BOD POD = air displacement plethysmography; BIS = bioelectrical impedance spectroscopy; DXA = dual-energy X-ray absorptiometry; SA = surface anthropometry.

Conclusion

In conclusion, consecutive-day PE was larger than same-day for FM and FFM estimates obtained from DXA, BOD POD, SA, and BIS (except for SA FM, which was marginally lower) in a cohort of muscular resistance-trained male athletes. This is despite PE limits for FM and FFM estimates being within acceptable precision thresholds, at least for DXA. Clearly all methods are subject to some imprecision due to daily biological fluctuations, especially BIS, which calculates physique traits from a TBW estimation. Given that both technical error and biological variation contribute to precision, we recommend the use of LSC values calculated from consecutive-day analysis when interpreting longitudinal change for true changes in physique. Application of DXA, BOD POD, or SA should be advocated over BIS for athletic populations where only small changes are observed over time.

Practical Implications

Adopting LSC values from consecutive-day analysis likely provide a more appropriate benchmark to assess meaningful change in body composition of athletic populations longitudinally.

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honestly, and without fabrication, falsification, or inappropriate data manipulation. The authors have no financial or personal conflicts of interest to declare. There were no funding sources for the present study.

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