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ARTICLE

Determining percentage body fat of male South African jockey apprentices irrespective of hydration status

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Objective: The aim was to determine the most appropriate field techniques to measure %BF when both euhydrated and dehydrated.
Design: A cross-sectional descriptive study was undertaken.
Setting: South Africa.
Subjects: 17 male apprentice jockeys (mean age 18.8 ± 1.7 years).
Outcome measures: Agreement of %BF results determined using predictive equations based on skinfold thickness measurements and bioelectric impedance analysis (BIA) with that of the reference method, euhydrated deuterium dilution (eDD).
Results: The mean %BF according to eDD was 9.5 ± 2.8%. The skinfold equations by Slaughter *et al*. (1988) for ages 8–18 years in either hydration state, Durnin and Womersley[1] using either Siri[2] or Brožek *et al.*[3] for ages 17–19 years when dehydrated only, and the Van Loan *et al.*[4] BIA equation when euhydrated only were the most acceptable methods.
Conclusion: Regardless of hydration status, the skinfold equation by Slaughter *et al.*[5] is recommended for jockey apprentices 18 years and younger. For those > 19 years, the hydration state must be confirmed prior to measurement. If euhydrated, the Van Loan *et al.*[4] BIA equation is recommended and if dehydrated the Durnin and Womersley[1] using either Siri[2] or Brožek *et al.*[3] is recommended.

Keywords bioelectric impedance analysis, body composition, deuterium dilution, jockey apprentice

Introduction

Horse racing relies on a handicapping system. Each horse in every race is assigned a specific weight (handicap) to carry, according to the ability of the horse. If the weight of the kitted jockey (including helmet, whip, saddle, boots, breeches and silks) immediately prior to the race exceeds the handicap by 500 g, the rider can be fined and/or suspended from racing for a period of time. Jockeys need to maintain their weight around the minimum handicap of 52 kg in South Africa as this allows increased opportunity to race ride to generate an income and thus pursue a successful career as a professional rider. A jockey apprentice is a professional jockey in training. An apprentice jockey is a professional jockey in training. Apprentices enter the South African Jockey Academy between the ages of 16 and 20 years and are required to obtain 50 race ride wins during their five-year apprenticeship to qualify as a professional jockey. Jockeys often resort to deleterious techniques of rapid weight loss in order to 'make' weight for a race, which increases the risk of occupational injury.[6] A similar prevalence of deleterious weight-making techniques has been reported in male jockey apprentices.[7,8] As it is easier and safer to 'make' a heavier weight than to lose weight before a race, it is critical for the jockey/apprentice jockey to maintain an optimal minimal weight all year round. As with other weight-making sports such as wrestling and boxing, it is essential that surplus weight in the form of body fat is managed, while maintaining the bone and muscle mass important for health and performance. It is not uncommon for weight-making athletes to manipulate their hydration status to reach bodyweight specifications, for example they may induce dehydration by fluid restriction or the use of saunas. An accurate, practical and affordable field technique for the measurement of percentage body fat (%BF), which is not significantly impacted by hydration status, is therefore essential.

Skinfold measurements are routinely used to measure the %BF of jockeys and other weight-making athletes due to their ease of use and low cost.[9–13] Accuracy, however, is impacted by the measurement technique, inter-tester variability, the number of sites measured[14] and by fluid and electrolyte changes.[15] Bioelectric impedance analysis (BIA) may be a more practical field method of measuring %BF as the measurement technique is simpler, thereby reducing inter-tester variability[16] although BIA is also potentially impacted by hydration status.[17]

For weight-making athletes to maintain a low %BF in order to compete optimally, the monitoring of body fat levels is crucial, making it necessary to identify a practical field method that is an accurate predictor of %BF regardless of hydration status. This necessitated the validation of skinfold and BIA equations that are acceptably accurate under conditions of both euhydration and dehydration.

Methods

Study design overview

Ethics approval was granted by the Biomedical Research Ethics Committee (BE212/16) of the University of KwaZulu-Natal.

Permission to conduct the study at the jockey academy was obtained from the principal. All male jockey apprentices enrolled in the apprenticeship programme and resident at the Summerveld campus of the SAJA from June to September 2016 were invited to participate in this cross-sectional descriptive study. Female apprentices were not included due to the small sample of female apprentices. Apprentices who left the academy or obtained their professional licence during data collection were excluded from analysis. Exclusion criteria included known disorders that could impact water balance, such as renal failure.

Prior to commencement, voluntary written informed consent was obtained from all apprentices aged 18 years and older. An assent form was completed by those younger than 18 years and written informed consent was obtained from their parent or legal guardian.

Data were collected at the SAJA on a rest day (usually Sunday) following an overnight fast beginning at 9 pm. At 5 am, the apprentices' hydration status was determined using urine specific gravity (USG). Their baseline saliva was sampled and they consumed the baseline dose (30 g) of deuterium oxide followed by two 50 ml doses of water. Bodyweight was measured in minimal clothing (underwear) post urination followed by height measurement. During data collection these measurements were taken by the same research assistant. Seven skinfold sites (triceps, biceps, subscapular, supra-iliac, abdominal, medial calf and frontal thigh) were measured by the South African Jockey Academy (SAJA) level 1 ISAK certified sport scientist. After measurements were complete, the apprentices retired to their dormitories to sleep. Four hours later, they returned to the data collection area for the follow-up saliva sample. Measurements were taken on two separate days: initially when dehydrated and then repeated when euhydrated. It was not necessary to implement a protocol to induce dehydration, as on the first day of data collection all apprentices presented in a dehydrated state and therefore one can assume that they were in a permanent state of dehydration. After a wash-out period of at least one week after the initial measurements in the dehydrated state were taken, a hydration protocol was followed for three days prior to repeating the measurements in a euhydrated state. This protocol was supervised by the SAJA dietitian, and involved a stipulated amount of fluid and electrolyte-rich snacks to be consumed daily, including two bottles of 500 ml Energade Lite, two cans of 330 ml diet cold drink (Coke Zero/Lite), one 250 ml bottle of Future Life Smart Drink, one 30 g packet of Lays crisps and one 50 g Future Life Smart bar. The SAJA dietitian monitored and recorded daily the compliance of each apprentice with this protocol. The SAJA sports scientist measured the USG daily for the three days prior to data collection to ensure euhydration on the day of data collection.

Urine specific gravity

The midstream urine sample was analysed immediately using a digital hand-held pocket refractometer (ATAGO PAL-10S, ATAGO, Tokyo, Japan) according to the manufacturer's standard operating procedures (SOP). Hydration status was classified as: euhydration USG $\leq$ 1.020 g/ml; mild to moderate dehydration USG $>$ 1.020 g/ml to $<$ 1.030 g/ml and severe dehydration USG $\geq$ 1.030 g/ml.[18,19]

Deuterium dilution technique

Deuterium dilution (DD) was used as the reference method for validation of body composition. The International Atomic Energy Agency (IAEA) standard operating procedures (SOP) were followed.[20] The IAEA equations were used to determine fat-free mass (FFM) (kg), fat mass (FM) (kg) and %BF. Due to statistically significant differences between the euhydrated and dehydrated FFM, FM and %BF results from DD, only the euhydrated DD (eDD) values were used as the reference standard. The technique assumes a constant hydration of 72–73%, therefore variations in hydration status can confound the results.[21,22]

Anthropometry

Weight and height

Weight (Seca 437 scale, Seca, Hamburg, Germany) was assessed in minimal clothing post urination and reported to the nearest 100 g. Stature was measured to the nearest mm using a stadiometer (height rod Seca 217, Seca, Hamburg, Germany). All measurements were repeated twice and an average value used, unless there was more than 100 g or 0.2 cm difference in measurements, in which case a third measurement was taken and the mean of the two closest readings was used.

Body mass indices

Body mass index (BMI) was calculated by dividing weight in kilograms (kg) by height in metres squared (m^2). If 19 years or younger, BMI was classified according to the World Health Organization (WHO) *Z*-scores[23], and if older than 19 years by Golden and Golden.[24]

Fat-free mass index (FFMI) and fat mass index (FMI) were calculated by dividing fat-free mass (kg) and fat mass (kg) respectively by height in m^2. If younger than 18 years, these were classified according to the recommendations of Weber *et al.*[25] If 18 years and older, the recommendations of Schutz *et al.*[26] were used. Both classifications correspond to the BMI cut-off points of the WHO.[23]

Skinfold measurements and equations

Triceps, biceps, subscapular, supra-iliac, abdominal, medial calf and frontal thigh skinfold sites were measured with callipers (Lange Skinfold Calliper, BETA Technology incorporated, Cambridge, MD, USA) using the techniques of ISAK.[27] To reduce inter-tester variability, the same SAJA ISAK certified sport scientist measured all the skinfolds. Measurements were repeated twice and the average value used, unless there was a 1 millimetre difference in the readings, in which case a third measurement was taken and the mean of the two closest readings was used.

Prediction equations for %BF or body density (BD) were included if they had been used in previous studies investigating jockeys[1,28] or if they were age-appropriate to the apprentice population (Table 1). To convert BD into %BF, the Siri[2] and Brožek *et al.*[3] equations were applied. Age-appropriate equations were used and compared with the eDD mean value of the same group. Where authors had provided separate equations for separate age groups, the results were separated and analysed accordingly.

Bioelectrical impedance analysis and prediction equations

Single-frequency bioelectrical impedance was measured using the BODYSTAT®1500 machine (Bodystat Ltd, Cronkbourne, Douglas, Isle of Man) according to the manufacturer's SOP. The BODYSTAT®1500 machine determined %BF from impedance using its own undisclosed equation. The test was

Table 1: Skinfold equations used to calculate percentage body fat

Author(s)	Reference population	Age range (years)	Equation[a]
Sloan[29,b]	White male non-athletes	18–26	BD = 1.1043–0.001327(thigh) − 1.001310(subscapular)
Durnin and Rahaman[30,b]	Male non-athletes[c]	12–17	BD = 1.1533–0.0643(LOG sum biceps, triceps, subscapular, supra-iliac)
	Male non-athletes[c]	18–30	BD = 1.1610–0.0632(LOG sum biceps, triceps, subscapular, supra-iliac)
Forsyth and Sinning[31,b]	Male athletes[c]	19–22	BD = 1.103–0.00168(subscapular) − 0.00127(abdominal)
Durnin and Womersley[1,b]	Male non-athletes[c]	17–19	BD = 1.162–0.063(LOG sum biceps, triceps, subscapular, supra-iliac)
	Male non-athletes[c]	20–29	BD = 1.1631–0.0632(LOG sum biceps, triceps, subscapular, supra-iliac)
Lohman[32,c]	White male non-athletes	'college-age'[d]	BD = 1.0982–0.000815(sum triceps, abdominal, subscapular) + 0.0000084(sum triceps, abdominal, subscapular)^2
Jackson and Pollock[33]	Male non-athletes[c]	18–61	%BF = 0.29288(sum abdominal, triceps, thigh, supra-iliac) − 0.0005(sum abdominal, triceps, thigh, supra-iliac) ^{2} + 0.15845A–5.76377
Withers *et al.*[28,b]	Male non-athletes[c]	15–39	BD = 1.0988–0.0004(sum triceps, biceps, subscapular, supra-iliac, abdominal, medial calf, thigh)
Slaughter *et al.*[5]	Both black and white male non-athletes	8–18	%BF = 0.735(sum triceps and calf) + 1
Deurenberg *et al.*[34,b]	Male non-athletes[c]	7–20[e]	2SF: BD = 1.1132–0.0410(LOG sum biceps and triceps) 4SF: BD = 1.1324–0.0429(LOG sum biceps, triceps, supra-iliac, subscapular)
Peterson *et al.*[35]	White male non-athletes	18–56	%BF = 20.94878 + 0.1166A–0.11666Ht + 0.42696(sum triceps, subscapular, supra-iliac, thigh)–0.00159(sum triceps, subscapular, supra-iliac, thigh)^2
Evans *et al.*[36]	Both black and white male non-athletes	18–26	%BF = 8.997 + 0.24658(sum abdominal, thigh, triceps) − 6.343–1.998Ra

BD: body density. n/a: not applicable. %BF: percentage body fat. A: age (years). Wt: weight (kg). Ht: height (cm). 3SF: equation by author(s) involving three skinfold measurements. 7SF: equation by authors(s) involving seven skinfold measurements. Ra: race, where white = 0 and black = 1.
[a]Skinfolds measured in mm.
[b]BD translated into %BF using the equations by Siri[2] and Brožek *et al.*[3]
[c]Race was not stated.
[d]Age range suggested is 18–24 years. Mean age was 20.4 years for the cross-validation sample with no standard deviation given.
[e]Equation used was recommended for post-pubescent males. Mean age of this group was 16.8 ± 36.[34]

Table 2: Equations used to calculate percentage body fat from resistance

Author(s)	Reference population	Age range (years)	Equation
Segal *et al.*[38,a]	Male non-athletes[b]	17–62	FFM = 0.0006636 Ht^2– 0.02117$R_{50\ KHz}$ + 0.62854 Wt–0.1238A + 9.33285
Gray *et al.*[39]	Male non-athletes[b]	19–74	FFM = 0.00139 Ht^2– 0.0801 $R_{50\ KHz}$ + 0.187 Wt + 39.83
Van Loan *et al.*[40]	Male non-athletes[b]	18–32	FFM (kg) = 0.51 Ht^2/ $R_{50\ KHz}$ + 0.33 Wt + 1.69 + 3.66
Deurenberg *et al.*[41]	Male non-athletes[b]	16–83	FFM (kg) = 0.34 Ht^2/ $R_{50\ KHz}$ + 0.1534 Ht + 0.273 Wt–0.127A + 4.56–12.44
Lohman[42]	Male non-athletes[b]	18–29	FFM (kg) = 0.485 Ht^2/ $R_{50\ KHz}$ + 0.338 Wt + 5.32
Houtkooper *et al.*[43]	White male non-athletes	10–19	FFM (kg) = 0.61 Ht^2/ $R_{50\ KHz}$ + 0.25 Wt + 1.31
Sun *et al.*[44]	Male non-athletes[b]	12–94	FFM (kg) = 0.65 Ht^2/ $R_{50\ KHz}$ + 0.26 Wt + 0.02$R_{50\ KHz}$–10.68

Ht: height (cm); $R_{50\ KHz}$: resistance at a frequency of 50 KHz; FFM: fat-free mass; $Z_{50\ KHz}$: impedance at a frequency of 50 KHz.
[a]Equation recommended for males with a %BF less than 20% was used.
[b]Race was not stated.

repeated and, if the impedance value differed by more than 1 ohm, the test was repeated for a third time and the mean of the two closest values was used.

The BODYSTAT®1500 machine measures *Z* at a frequency of 50 KHz only, and does not measure resistance (R) and reactance (*X*) values separately. Although not recommended to be used interchangeably,[37] resistance (*R*) values were substituted for impedance (*Z*) values given by the machine into age- and gender-appropriate equations (Table 2) in order to determine if equations other than that of the undisclosed equation of the BODYSTAT®1500 produced more accurate results. Fat mass was determined by subtracting FFM from total bodyweight. The FM was then divided by the total bodyweight and multiplied by 100. Values were compared to the mean value of the same group according to eDD.

Classification of percentage body fat

Percent body fat was classified according to Borrud *et al.*[45] standards for apprentices younger than 20 years and by Gallagher *et al.*[46] standards for those aged 20 years and older. A level of 4–6% was used as the minimum limit of body fat (essential fat) for healthy active males[47].

Statistical analysis

The Statistical Package for the Social Sciences (SPSS) version 24.0 (IBM Corp, Armonk, NY, USA) was used. Descriptive statistics, including means, standard deviations, ranges, frequencies and percentages (proportions), were used to describe the data.

Sample size estimations were conducted based on the number of apprentices enrolled at the Summerveld campus at the academy. Lin's concordance correlation coefficient (CCC) was used to assess agreement between the %BF results of the field methods with the gold standard (eDD),[48] in order to determine whether the results found can be generalised to the South African jockey apprentice population. Only eDD was used for this assessment as the objective was to determine which field methods when dehydrated compare favourably to the gold standard (eDD) as eDD assumes a constant hydration of 72–73%, therefore variations in hydration status can confound the results.[21,22] The equations with the highest values for CCC, which were those with a CCC value of 0.380 or more in this study due to the overall low CCC values, were interpreted as acceptable agreement, and were further analysed using Bland–Altman plots to evaluate bias within the mean differences.[49] Equations with a mean difference < 0.65 in both directions, and a trend line slope < 0.9 were considered the most comparable to eDD following visual inspection of the Bland–Altman plots.

Results

Characteristics of the participants

Seventeen of the 19 male jockey apprentices training at the campus from June to September 2016 (84%) participated. The mean age was 18.8 ± 1.7 years. Two were excluded as one obtained a professional licence and the other did not complete his apprenticeship.

Hydration status

The mean USG in their habitual state of dehydration was 1.027 ± 0.003 g/ml with 19% (3/16) being severely dehydrated. The mean USG was significantly lower when euhydrated (1.011 ± 0.005 g/ml ($p < 0.001$).

Weight, height and body mass index

The mean weight was 50.4 ± 3.5 kg, height 1.62 ± 0.06 m and BMI 19.2 ± 1.1 kg/m^2. For those ≤ 19 years (10/17), 60% (6/10) were stunted, with a height-for-age *Z* score less than −2; according to the WHO (2007) growth indicator classification for children, none were severely stunted according to this classification (Z score less than −3) and all had a normal BMI.[23] Only one (6%) > 19 years was moderately malnourished according to BMI.[24]

Body composition determined by the reference method: euhydrated deuterium dilution

The mean %BF was 9.5 ± 2.8%. For those < 20 years, the mean %BF (10.2 ± 2.8%) was lower than the normal age-appropriate range for males (13.7–31.2%)[45] and 92% (12/13) were underfat, meaning that their individual %BF was less than this normal range. For those ≥ 20 years the mean %BF (7.3 ± 1.2%) was within the normal range for adult male athletes (5.0–10.0%)[50] and none were underfat according to this range. Two (12%, 2/17) had extremely low fat levels within the 'essential' fat range (4–6%).[47] Although most (88%, 15/17) were underfat as determined by %BF, the FMI (1.8 ± 0.6 kg/m^2) classified fewer (65%, 11/17) as underfat.[25,26] Most (88%, 15/17) had a normal lean mass (17.4 ± 1.1 kg/m^2) according to the FFMI, with 2 (18%, 2/17) being classified as underlean, meaning that their FFMI was less than the normal age-appropriate range.[25,26]

Body composition as determined by field methods

Skinfold measurements

Of the 24 skinfold equation combinations (where the application of Siri[2] or Brozek *et al.*[3] represent separate equations), 3 (12%) were considered to have acceptable agreement with eDD when euhydrated. These included, using either the Siri[2] or Brozek *et al.*[3] equations to convert BD to %BF, that of Durnin and Womersley[1] for the 17–19-year age group; as well as the Slaughter *et al.*[5] equation.

When dehydrated, 4 of the 24 equations (17%) were considered to have acceptable agreement with eDD, including, using the Brozek *et al.*[3] equation to convert BD to %BF, that of Forsyth and Sinning[31], the Durnin and Womersley[1] for the 17–19-year age group using either the Siri[2] or Brozek *et al.*[3] equations to convert BD to %BF, as well as the Slaughter *et al.*[5] equation.

Bioelectric impedance analysis

The Van Loan *et al.*,[4] Lohman[42] and Houtkooper *et al.*[43] BIA equations were considered to have acceptable agreement with eDD when euhydrated, and none were considered to have acceptable agreement when dehydrated

Predictive equations most comparable to the reference standard

A Bland–Altman analysis was then applied to the equations producing measures with acceptable agreement with eDD to determine which were the most comparable to the reference standard with the lowest levels of bias. According to the criteria applied to the Bland–Altman analysis, the equations most likely to be accurate were the skinfold equations by Slaughter *et al.*[5] for those aged 8 to 18 years, in either hydration state; Durnin and Womersley[1] using either Siri[2] or Brožek *et al.*[3] for the 17–19-year age group when dehydrated only; and the Van Loan *et al.*[4] BIA equation for ages 18 to 32 years when euhydrated only (Figure 1).

The mean of the differences is a measure of the bias and indicates whether the bias is positive or negative. The upper and lower limits of agreement (ULOA and LLOA) indicate the range in which 95% of the values fall. The trend line indicates if there is over- or underestimation in any specific range of the measurements.

Discussion

This study aimed to determine suitable field methods for the acceptably accurate measurement of %BF in South African apprentice jockey regardless of their hydration state. Few studies currently exist that validate field methods of measuring %BF against reference methods in jockeys and other weight-making athletes, and none as such in jockey apprentices prior to this study. The only regression equations to date used in the published studies on jockeys have been that of Durnin and Womersley[1] and Withers *et al.*[28] in combination with the Siri[2] equation. The Withers *et al.*[28] equation has been shown to be acceptably comparable to DXA by Warrington *et al.*[11] in moderately dehydrated professional Irish jockeys and by Dolan *et al.*[8] in professional Irish jockeys, but not professional Irish boxers, although hydration status was not assessed. Interestingly, the Withers *et al.*[28] skinfold equation used was not found to be acceptably accurate in the current study. Although the Durnin and Womersley[1] skinfold equation has been used to measure the %BF of

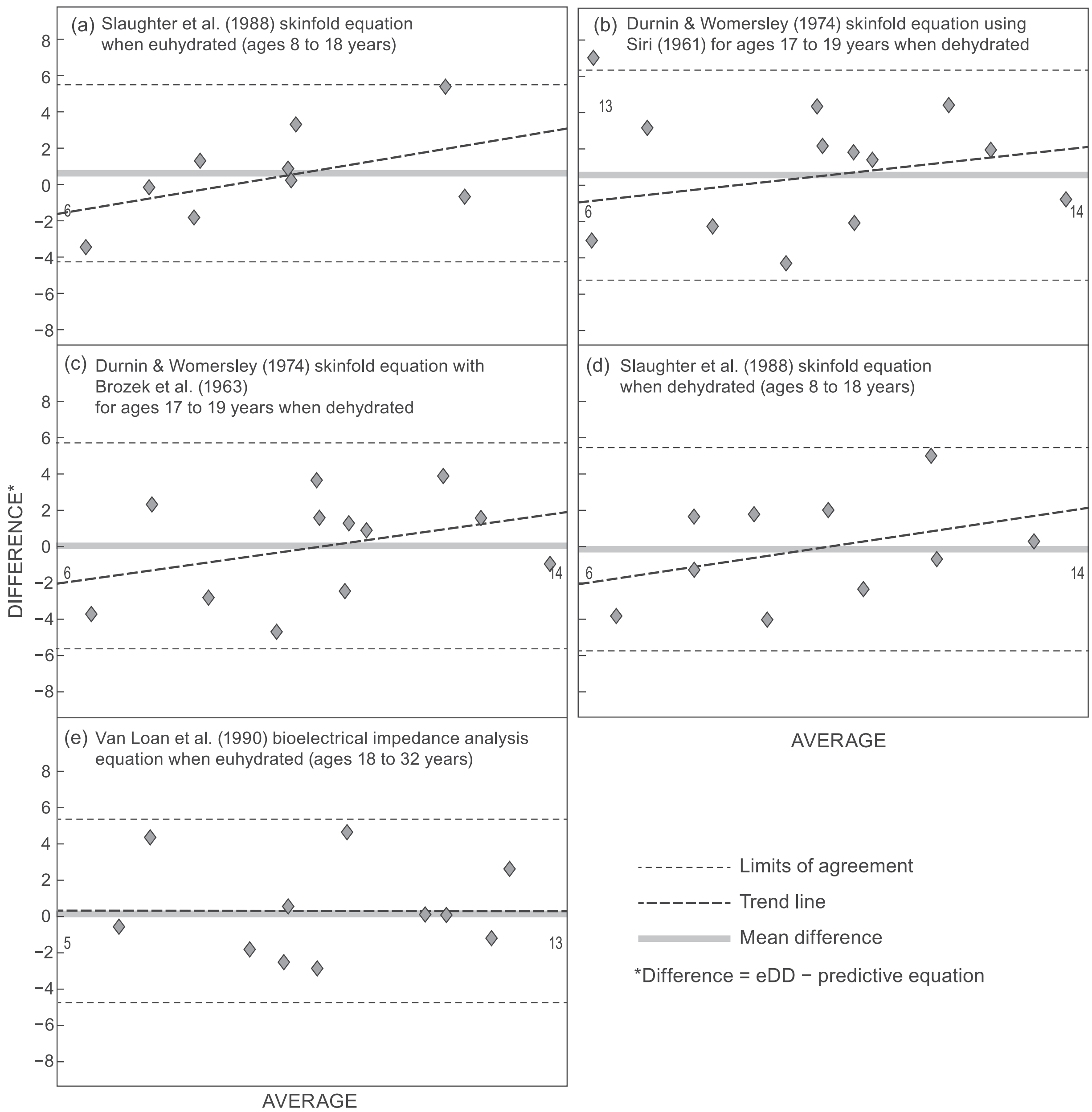

Figure 1: Bland–Altman plots equations most comparable to the reference standard with the lowest levels of bias.

professional jockeys in Hong Kong by O'Reilly *et al.*,[12] it had not been validated against a reference method in jockey or weight-making athlete populations.

Due to the acceptable level of bias in both hydration states, the skinfold equation by Slaughter *et al.*[5] can be recommended for apprentices aged ≤ 18 years. This equation requires only two skinfolds (tricep and calf) making it a simpler equation to apply, thereby reducing the risk of error. If dehydrated and 19 years old, the Durnin and Womersley[1] using either Siri[2] or Brozek *et al.*[3] can be recommended. This equation requires four skinfolds (bicep, tricep, sub-scapular and supra-iliac), thereby also relatively reducing the risk of error. It is still essential that the correct techniques for skinfold measurement are strictly adhered to, that calibrated and validated callipers such as Lange or Harpenden are used and that measurements are taken by an individual trained in recognised standards of measurement, such as ISAK.

For those > 19 years, it is essential to ensure euhydration prior to measurement, in which case the Van Loan *et al.*[4] BIA equation can be recommended. This further emphasizes the need to focus on healthy hydration in this population. This may also mean that apprentices older than 19 years will be unable to accurately measure their %BF on or shortly before race days as, although healthy hydration should be encouraged, it is still unlikely that an apprentice/jockey will be euhydrated at these times, despite BIA being useful in instances where it is not possible to have a single tester who is appropriately trained to measure skinfolds, for example, as race days are held in different locations.

Measurement of %BF by BIA is known to be significantly affected by hydration status,[15,51] although it had yet to be tested in a jockey apprentice population prior to this study, and many of the equations used in this study had not been tested for impact by dehydration before. In the present study, 62% (5/8) of the BIA equations were significantly impacted by dehydration.

The literature regarding the impact of hydration status on the % BF determined by skinfold measurements suggests that there is no significant impact of dehydration on the measurement of % BF from skinfolds.[7,52,53] It can also be noted that, in the present study, only 30% (6/20) of the skinfold equation combinations were significantly influenced by dehydration, due to statistically significant differences between euhydrated and dehydrated % BF values.

An unexpected finding was the state of chronic dehydration of the apprentice jockeys (1.027 g/ml) on non-race days, as most were able to meet their weight requirements without resorting to weight-making techniques. A study involving Irish jockey apprentices found that they were euhydrated (USG 1.017 ± 0.005 g/ml) on non-race days.[54] Warrington *et al.*[13] reported dehydration (USG 1.028 ± 0.005 g/ml) in professional Irish jockeys on race days similar to the apprentices in this study on a non-race day. Acute and chronic dehydration in Irish and British jockeys has been found to negatively impact racing performance by reducing peak work capacity, increasing heart rate and rate of perceived exertion and reducing chest and leg strength and pushing frequency.[9,55] Chronic dehydration may also have long-term health implications, although this could not be associated with renal dysfunction in British jockeys.[6] This clearly necessitates education on the importance of hydration, and regular monitoring of hydration status for jockey apprentices, which has been implemented at SAJA since this study was conducted.

Only two apprentices were within the 'essential' fat range, so arguably their %BF was too low and needed correcting. Both of them had a normal BMI, therefore BMI does not provide sufficient insight into body composition, emphasising the importance of alternative field measurements of %BF. According to either FMI or %BF, 65% and 88% were underfat respectively and only 2 and 5 of the 17 apprentices respectively could reduce their fat mass as they exceeded the lower cut-off of normal. A small amount of storage fat is important, over and above essential fat, to avoid the risk of compromising FFM when there is an energy deficit, as, once the essential fat level has been reached, muscle is catabolised for energy.[47] It is not recommended therefore that all of the apprentices be encouraged to reduce their FM as this presents a high risk of compromising FFM. As recommendations for reducing FM should be individualised, accurate body composition assessment is essential. Only two were classified as underlean according to FFMI[25,26] and should be encouraged to improve this through a combination of nutritional intervention and strength training.

Study limitations

This study was not without limitations. The sample size was small as the total population of apprentice jockeys in South Africa was few; however, the high response rate allowed for an adequate representation of the population. The more cost effective 2 phase BIA machine does not offer separate values for resistance and reactance, which limited the number of BIA equations that could be applied to the data.

Conclusion

Recommendations to reduce weight in this population should be individualised and based on body composition determined by accurate methods of measurement.

Regardless of hydration status, the skinfold equation by Slaughter *et al.*[5] is recommended for jockey apprentices 18 years and younger, for those > 19 years euhydration must be confirmed prior to measurement, in which case the Van Loan *et al.*[4] BIA equation can be recommended and, if dehydrated and 19 years old, the Durnin and Womersley[1] using either Siri[2] or Brozek *et al.*[3] can be recommended. If older than 19 years and dehydrated, %BF can therefore not be measured accurately.

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Authorships – The study was designed by Dr C. Biggs and Miss E.L. Illidge; data were collected by Ms E.L. Illidge, Dr C. Biggs, Ms K. Krog, Ms T. Mason and Ms M. Read; data interpretation and manuscript preparation were undertaken by Dr C Biggs and Ms EL Illidge. All authors approved the final version of the paper.

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