Lean Body Mass Index is an Indicator of Body Composition for Screening Prospective Young Adult Soccer Players

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The present study aimed to clarify anthropometry and body composition variables which can discriminate prospective young adult soccer players from others. Thirty-nine collegiate male soccer players were assigned to two groups; players who succeeded in signing a contact as a professional on graduation (N = 10, PRO) and others (N = 29, CON). Body height (BH), body mass (BM) and percent body fat (%Fat) were measured using a stadiometer and a bioelectrical impedance analyzer. Using data on BH and BM, we calculated body mass index (BMI) and reciprocal ponderal index (RPI). Lean body mass (LBM) was calculated from BM and %Fat, and divided by BH (LBM/BH) or BH^2 (LBM/BH^2). LBM/BH^2 was significantly higher in PRO (19.2 ± 0.6 kg/m^2) than in CON (18.6 ± 0.9 kg/m^2), but there were no significant group differences in other variables. BH was significantly related to LBM/BH (r = 0.608, p<0.0001) and RPI (r = 0.331, p<0.05), but not to BMI and LBM/BH^2 across subjects. Allometric scaling (b) obtained from exponential relationship between BH and each of BM and LBM was 2.354 for BM and 1.927 for LBM. The current findings indicate that LBM/BH^2 is independent of body height and it can be a beneficial index for screening prospective young adult soccer players.

Keywords: body mass index, reciprocal ponderal index, body shape, body size

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1. Introduction

Soccer coaches and scientists are interested in key factors that can discriminate successful players and team from less successful ones (Reilly et al., 2000). In general, elite soccer players are taller, heavier and muscularity (le Gall et al., 2010; Nevill et al., 2009; Reilly et al., 2000). In addition, it has been shown that not only body size (e.g. body height and mass) but also body shape parameters such as body mass index (BMI) and reciprocal ponderal index (RPI), which are calculated from body height (BH) and body mass (BM), can be outcome parameters for discriminating successfully soccer players from others (le Gall et al., 2010; Nevill et al., 2009; Rebelo et al., 2013). le Gall et al. (2010) revealed that elite youth soccer players who succeeded in singing a contract as a full-time professional had greater body size than those who did not acquire a professional contract on graduation from an elite youth academy. Furthermore, RPI has been shown to be higher in top six teams of England premier league than bottom rank teams in the 2003-04 season (Nevill et al., 2009). Taken together, it is reasonable to assume that anthropometrical variables may be useful outcome measures for screening elite soccer players.

In addition to body size, body composition has also been shown to be one of the indicators for screening prospective soccer players. In fact, Japanese professional players over 23 years have great LBM relative to BH (LBM/BH), compared to elite youth ones under 22 years (Hoshikawa, 2009). According to allometric scaling, BH is cubically proportional to BM, and LBM (Asmussen & Heeboll-Nielsen, 1955). If so, normalizing LBM by BH (i.e., LBM/BH) would produce a bias, being dependent on BH. Furthermore, an empirical study has shown that adult humans are not geometrically similar to each other (Nevill et al., 2004). This suggests that mass components cannot be simply normalized in accordance with the allometric scaling. On the other hand, Hattori (1991) have demonstrated that LBM/BH^2 and FM/BH^2, defined as

LBM index and FM index, are independent of BH for Japanese college student. Considering this finding, LBM index rather than LBM/BH would be more suitable for screening prospective young adult soccer players regardless of difference in BH.

In Japan professional league, the percentage of players who experienced university soccer league increases. Therefore, we considered that elucidating the differences in anthropometry and body composition variables between players who signed to professional soccer teams on graduation and others who did not is beneficial for coaches to design training program and to screen prospective soccer players. The purpose of this study was to elucidate anthropometry and body composition variables which can be outcome measures for screening prospective young soccer players, independent of body size.

2. Methods

2.1. Subjects

Thirty-nine collegiate male soccer players were assigned to two groups; one players who succeeded in signing a contact as a professional on graduation (N = 10; 2 players for 1st division, 3 players for 2nd division, 2 players for 3rd division, and 3 players for Japan football league, PRO) and those who did not (N = 29, CON). Data was collected over 3 years from 2013 to 2015. They were free of cardiovascular, metabolic, immunologic disorders and/or orthopedic abnormality, and were not using any medications that affected their muscle functions. All subjects have experienced soccer for over 6 years. Subjects conducted specific training programs for soccer at least for 2 h/day on 6 days/week. This study was approved by the ethical committee of the National Institute of Fitness and Sports in Kanoya and was consistent with its requirements for human experimentation. Prior to the experiment, all subjects were informed of the experimental procedures of this study and possible risks of the measurements beforehand. Written informed consent was obtained from each subject.

2.2. Measurement of body size and body composition

BH was measured using a stadiometer to the nearest 0.1 cm. BM and percent body fat (%Fat) were determined by a leg-to-leg bioelectrical impedance analyzer with a computer-programmed athletic mode (DC-320, TANITA, Japan) to the nearest 0.1 kg and 0.1%, respectively. The measurements of body composition were conducted after 16:00 in both groups. The subjects restrained from alcohol intake during 24 h and from taking a meal during 4 h prior to the measurement. The room temperature was usually kept at 23°C. BMI (kg/m^2) and RPI (cm/kg$^{0.333}$) were calculated from BH and BM (Nevill et al., 2009). FM was calculated from BM and %Fat, and normalized to BH squared (FM index, kg/m^2) (Hattori, 1991).

To examine the reproducibility of the %Fat measurement, we determined the %Fat with the device for 5 young adult men. As the result, the mean values of % Fat were 20.9 ± 2.7% for the 1st measurement, and 19.5 ± 2.9% for the 2nd measurement. The error between 1st and 2nd measurements was 1.4 ± 0.5%. The intra-class correlation coefficient for the % Fat measurement was 0.874. This value satisfied a criteria for the reproducibility of the measurement (>0.80)(Landis & Koch, 1977). Furthermore, leg-to-leg bioelectrical impedance analysis is not a valid estimate of LBM (Loenneke et al., 2012). To confirm accuracy of the %Fat and LBM values obtained from the device, therefore, we compared those values with those obtained from a whole-body dual-energy X-ray absorptiometry (DXA) scanner (Hologic Delphi A-QDR, USA) for 32 collegiate soccer players (BH, 174.4 ± 7.0 cm; BM, 69.2 ± 6.5 kg; BMI: 22.8 ± 1.3 kg/m^2; RPI, 42.5 ± 1.1 cm/kg$^{0.333}$). The results revealed that the average value of the %Fat was not different between the two methods, but DXA-derived LBM was significantly lower than the bioelectrical impedance analyzer, and there were significant systematic errors in %Fat and LBM, depending on body size. To correct the error, therefore, we conducted a Stepwise multiple regression analysis and developed the equation for estimating LBM; LBM (kg) = 13.589 + 0.741 × BM (kg) – 0.642 × %Fat (%) [R^2 = 0.92, SEE (%SEE) = 1.2 kg (2.1%)]. LBM was divided by BH (LBM/BH; kg/m) (Hoshikawa, 2009) and BH squared (LBM index; kg/m^2) (Hattori, 1991).

2.3. Statistical analysis

Descriptive data are presented as means ± SDs. Independent variables in this study are BH, BM, BMI, RPI, %Fat, FM, FM index, LBM, LBM/BH, and

LBM index. Firstly, we confirmed the homogeneity of each variable among two groups on the basis of the results of Levene's test of equal variances. Group-related differences in the independent variables were tested an unpareid t-test. Effect size was determined using the Cohen's d method and its magnitude was interpreted in accordance with the recommendations of Hopkins (Hopkins, 2010), defining <0.2, 0.2-0.6, 0.6-1.2, 1.2-2.0, 2.0-4.0, and >4.0 as trivial, small, moderate, large, very large, and nearly perfect, respectively. Pearson's product-moment correlation analysis was performed to determine associations between the independent variables and anthropometry parameters. Correlation coefficients were interpreted as being weak (0.1-0.3), moderate (0.4-0.6), and strong (>0.7) according to earlier study (Styles et al., 2016). To elucidate whether BM and LBM was proportional to BH, allometric scaling was calculated from the following equation; BM or LBM = a × BH^b, where a and b are the scaling constant and scaling exponent. Statistical significance was set at $p<0.05$. All statistical procedure was conducted by using a statistical software (SPSS 22.0 for windows, IBM, Japan).

3. Results

Table 1 presents comparison of physical characteristics between PRO and CON. LBM index was significantly higher in PRO (19.2 ± 0.6 kg/m^2) than in CON (18.6 ± 0.9 kg/m^2) ($p<0.05$, t = 2.07, d = 0.61). LBM/BH tended to be higher in PRO (33.4 ± 2.0 kg/m) than in CON (32.1 ± 1.9 kg/m), but the

Table 1 Comparison of physical characteristics between PRO and CON groups

	PRO (N = 10)	CON (N = 29)	ES
Age, years	21.3 ± 0.6	22.1 ± 0.7	
Body height, cm	173.9 ± 7.4	173.0 ± 6.5	0.14
Body mass, kg	69.6 ± 9.1	66.6 ± 7.6	0.39
BMI, kg/m^2	22.9 ± 1.5	22.2 ± 1.7	0.43
Percent body fat, %	10.8 ± 2.1	11.4 ± 2.7	0.24
Fat mass, kg	7.6 ± 2.4	7.7 ± 2.5	0.04
FM index, kg/m^2	2.5 ± 0.6	2.6 ± 0.7	0.15
Lean body mass, kg	58.3 ± 5.8	55.6 ± 4.8	0.55
LBM/BH, kg/m	33.4 ± 2.0	32.1 ± 1.9	0.69
LBM index, kg/m^2	19.2 ± 0.6	18.6 ± 0.9*	0.61
Reciprocal pondel index, cm/kg$^{0.333}$	42.4 ± 0.8	42.7 ± 1.1	0.30

Values are presented as means ± SDs. ES, effect size (Cohen's d)

* significantly different from PRO at $p<0.05$.

BH, body height; BMI, body mass index; FM, fat mass; LBM, lean body mass difference did not reach to the level of significance (p = 0.066, t = 1.92, d = 0.69). There were no significant differences in BMI and RPI between the two groups. BH was significantly related to LBM/BH (r = 0.608, p<0.0001) and RPI (r = 0.331, p<0.05) across subjects, but not to BMI and LBM index (r = -0.050-0.195, p>0.05). LBM were significantly associated with BH (r = 0.844, p<0.0001) and BM (r = 0.967, p<0.0001) and body shape parameters (r = 0.473-0.938, p<0.05), respectively, except for RPI (r = -0.176, p>0.05). There were significant correlations among the body shape parameters (**Table 2**). Allometric scaling (b) in proportion to BH was 2.354 for BM, and 1.927 for LBM. Furthermore, the significant correlations among the measured variables for PRO group was similar to those for CON group (**Table 3**).

4. Discussion

The main findings obtained here are that, for young adult soccer players, 1) LBM index was independent of BH, and 2) LBM index for PRO was significantly higher than CON, but there were no significant group differences in other variables. These findings suggest that LBM index can be a beneficial index for screening prospective young adult soccer players from others, being independent of BH.

The average values of BH and BM in this study were almost the same as those for Japanese elite soccer players (Hoshikawa, 2009). BMI (22.2-22.9 kg/m^2) and RPI (42.4-42.7 cm/kg$^{0.333}$) for the players examined here are also similar to those reported for elite soccer players (22.1-23.2 kg/m^2 for BMI; 42.2-42.8 cm/kg$^{0.333}$ for RPI) (Hoshikawa, 2009; Nevill et al., 2009; Rebelo et al., 2013), being calculated from data presented in the literatures. However, LBM/BH (32.1-33.4 kg/m) and LBM index (18.7-19.2 kg/m^2) in the present study are relatively lower than the corresponding values in earlier studies (35.0-37.0 kg/m for LBM/BH, 20.3-21.0 kg/m^2) (Hoshikawa, 2009; Rebelo et al., 2013). Considering this, the collegiate prospective soccer players examined here may be less muscularity compared to elite young adult soccer players, regardless of similarity in body size.

LBM index for PRO was significantly higher than CON, regardless of similarity in body size. It leaves no doubt that taller/more muscular players have some physical advantages in soccer games. In general, taller individuals have relatively longer legs than shorter ones (Fredriks et al., 2005). Nevill et al. (2009) discussed that the players who have longer legs are more likely to be successful for tackling opposition players to gain possession, and for heading the ball in defense and in attack, and for closing down or limiting opposition players' ability to pass and distribute the ball. In the current results, however, no significant differences were found in the absolute values of body size and body composition. This implies that the absolute values of body size and body composition cannot be factors for screening prospective collegiate soccer players.

LBM index was significantly related to RPI and BMI, but significant group-related difference was observed in LBM index only. The observed

Table 2 Coefficients of correlation among body shape parameters across subjects

	BH	BM	BMI	RPI	%Fat	FM	FM index	LBM	LBM /BH	LBM index
BH		**0.796***	0.195	**0.331***	**0.245**	**0.494***	0.246	**0.844***	**0.608***	-0.050
BM			**0.747***	-0.306	**0.600***	**0.827***	**0.679***	**0.967***	**0.921***	**0.509***
BMI				**-0.860***	**0.707***	**0.795***	**0.832***	**0.638***	**0.824***	**0.879***
RPI					**-0.553***	**-0.508***	**-0.672***	-0.176	**-0.477***	**-0.871***
%Fat						**0.942***	**0.979***	**0.375***	**0.401***	0.305
FM							**0.961***	**0.656***	**0.655***	**0.419***
FM index								**0.473***	**0.545***	**0.484***
LBM									**0.938***	**0.490***
LBM/BH										**0.761***

* significantly correlation between the two variables at p<0.05.

BH, body height; BM, body mass; BMI, body mass index; RPI, reciprocal ponderal index; %Fat, percent body fat; FM, fat mass; LBM, lean body mass

Table 3 Coefficients of correlation among body shape parameters for each group

	BM	BMI	RPI	%Fat	FM	FM index	LBM	LBM /BH	LBM index
BH	**0.893***	0.483	0.204	0.392	0.629	0.426	**0.945***	**0.851***	0.279
	0.757*	0.092	**0.389***	0.217	**0.452***	0.195	**0.816***	**0.528***	-0.162
BM		**0.821***	-0.254	**0.734***	**0.902***	**0.773***	**0.987***	**0.990***	**0.668***
		0.717*	-0.305	**0.613***	**0.825***	**0.825***	**0.958***	**0.900***	**0.457***
BMI			**-0.758***	**0.948***	**0.961***	**0.961***	**0.727***	**0.852***	**0.944***
			-0.881*	**0.702***	**0.773***	**0.773***	**0.591***	**0.811***	**0.872***
RPI				**-0.762***	-0.603	**-0.769***	-0.111	-0.321	**-0.851***
				-0.549*	**-0.502***	**-0.672***	-0.160	**-0.499***	**-0.882***
%Fat					**0.948***	**0.993***	0.614	**0.730***	**0.833***
					0.949*	**0.980***	0.361	**0.387***	0.282
FM						**0.967***	**0.822***	**0.900***	**0.838***
						0.961*	**0.630***	**0.623***	**0.372***
FM index							**0.660***	**0.780***	**0.882***
							0.445*	**0.445***	**0.459***
LBM								**0.975***	0.575
								0.921*	**0.436***
LBM/BH									**0.741***
									0.752*

* significantly correlation between the two variables in PRO (upper) and CON (bottom) groups at $p<0.05$.

BH, body height; BM, body mass; BMI, body mass index; RPI, reciprocal ponderal index; %Fat, percent body fat; FM, fat mass; LBM, lean body mass

significant correlations may be due to that the three indices were calculated by using mass components (BM and LBM) and BH. As shown in **Table 2**, BM, BH, and LBM were highly correlated to each other. Thus, the associations among the variables, being used to calculate the three indices, might have resulted in significant correlations between LBM index and either BMI or RPI. In spite of the significant associations of RPI and BMI with LBM index, however, why the two indices had no significant group differences are unknown. Probably, inter-individual variations in each of three indices would have produced a difference in the results of an unpaired t-test between the two groups.

It is known that LBM is strongly related to BH (Kondo et al., 1994). Therefore, when one intends to assess muscularity relative to body size, LBM/BH is often calculated to normalize the difference in BH. The effect size for each of LBM/BH and LBM index was almost the same: 0.69 for LBM/BH and 0.61 for LBM index (**Table 1**), although the results of a Student's t-test did not show a significant group difference in LBM/BH. This suggests that not only LBM index but also LBM/BH can be a variable for discriminating collegiate soccer players. In the current results, however, LBM/BH was significantly related to BH regardless of group (**Table 3**). The corresponding relationship was not found for LBM index. This can be explained by the allometric scaling (b) of BM and LBM in proportion to BH. The allometric scaling for LBM was 1.927, being close to the value of BH^2. Thus, LBM index may be assumed to be a valid index reflecting the magnitude of muscularity relative to body size in young adult soccer players. In other words, it can say that taller players will be overvalued when LBM/BH is used.

Furthermore, LBM index as well as BMI and LBM/BH were significantly correlated to LBM, implying that these variables may be parameters of LBM. LBM is strongly related to one repetition maximum load during each of squat, deadlift, and bench press (Brechue & Abe, 2002). The corresponding relationships are remained even after normalizing by BH (Brechue & Abe, 2002), indicating that LBM in proportional to BH can be a parameter of force-generating potential. Taking these aspects into account, therefore, it may be assumed that young adult soccer players with high LBM index would have a greater force generation potential relative to body size as compared to players with low LBM index, and it might be a reason for discriminating them as players who succeeded in signing a contact as a professional on graduation.

There are some limitations in this study. Firstly, players have to be faster and more powerful than opponent to score goals or to stop goals being scored during a soccer game. For achieving these plays during games, athletic performance (e.g. jumping and sprinting) involved in strength/power generating capacity make important contributions to the performance potential of elite soccer players (Hoff & Helgerud, 2004; le Gall et al., 2010; Wisloff et al., 2004). Therefore, we should pay attention to the performance variables other than anthropometric parameters. Secondly, the independent variables were averaged across position. Position-related differences in body size and body shape parameters are found in the earlier studies (Lago-Penas et al., 2014; Nevill et al., 2009). Finally, the current findings were obtained from one team, and small sample size. Therefore, it is unclear whether the findings obtained here can be applied for other university soccer players. In either case, unfortunately, we did not have the relevant data, so further investigations are needed in these points.

5. Conclusion

This study demonstrates that lean body mass relative to body height squared can be a suitable index for screening prospective young adult soccer players, compared to other parameters such as body mass index, ponderal reciprocal index, and lean body mass relative to body height.

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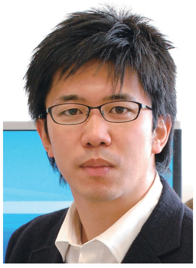

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