Total Body Water (TBW) Percentage and 3rd Space Water Were Risk Factors for Recruit Injuries in Lower Limbs: A Case-Control Study

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Research

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Abstract

Background: Recruit training injuries have caused serious problems for troop training and medical support. The lower limbs is the site where recruit injuries occur the most. Bio-impedance (BIA) measures body composition quickly and accurately. Our aim was to identify the risk factors for lower limbs training injuries to recruits due to body composition.

Methods: A total of 282 recruits were included. Before training, use BodyStat QuadScan 4000 multifrequency BIA system to measure the body composition of recruits. After training, they were divided into two groups according to the occurrence of lower limb training injuries. The basic characteristics of the two recruits were compared by Wilcoxon rank sum test. Receiver operator characteristic (ROC) curves was performed on the indicators with statistical difference between the two groups to find the cutoff point. Finally, multivariate logistic regression analysis was used to find the risk factors of lower limb training injuries.

Results: Compared with the lower limb uninjured group, the lean mass percentage ($P = 0.003$), TBW percentage ($P = 0.010$), extracellular water (ECW) percentage ($P = 0.023$), intracellular water(ICW) percentage ($P = 0.027$), 3rd space water ($P = 0.021$) and basal metabolic rate(BMR)/total weight ($P = 0.014$) of the lower limb injury group was higher. On the contrary, the body fat percentage ($P = 0.003$) and body fat mass index (BFMI) ($P = 0.005$) of the lower limb injury group was lower. The results of multivariate logistic regression analysis showed that TBW percentage > 65.350% ($P = 0.050$, OR=2.085) and 3rd space water >0.950 ($P = 0.045$, OR=2.342) were independent risk factors for lower limb injuries.

Conclusions: TBW percentage> 65.35% and 3rd space water >0.950 were independent risk of lower limb training injuries. These recruits need to be paid more attention during training.

Background

Recruit training injuries have placed a great burden on the training and medical treatment of troops[1]. The incidence of military training injuries for foreign male recruits reported in the reference is about 25% [1]. The incidence of Chinese recruit injuries was 21.04%[2]. The highest rate of training injuries is lower limb injuries[2, 3].

BIA is a fast, non-invasive, safe and inexpensive method for measuring body composition[4–6]. BIA has been used to monitor disease and nutritional status and predict prognosis[7–10]. It has been reported by many references that the measurement data of the BodyStat QuadScan 4000 multifrequency BIA system is reliable[6, 7, 11–13].

The influence of body composition on sports has attracted people's attention. For example, body composition affects the recovery of exercise performance[14], and differences in body composition between overtraining syndrome subjects and healthy subjects[15], and relationship between athletic performance and body composition[16].

Military training is also a special sport. Previous reference has attempted to use body composition analysis to predict the occurrence of training injuries[17]. However, the measurement of human body composition may have problems such as tedious measurement, poor accuracy, and low body composition parameters. In this study, we used the BodyStat QuadScan 4000 multifrequency BIA system for body composition measurement. And a case-control trial was designed to find the risk factors for recruit injuries.

Methods

Study design

A case-control study design was used. Recruits undergo the test was conducted at a recruit training base in the Chinese Army. BIA measurements before participating in recruit training. After 8 weeks of recruit training, the occurrence of recruit injuries was recorded. Recruits were divided into a lower limb injury group and a lower limb uninjured group. Analyze the relationship between lower limb training injuries and body composition.

Researchers assured recruits that participation in the study was voluntary and that non-participation would not affect training results or their military career.

Inclusion / Exclusion Criteria

All recruits in the recruit training base who have passed the enlistment medical examination can be included in this study. Recruits who do not adapt to the life of the army and retire halfway will be excluded from the study. In addition, invalid measurement data will be excluded from the study. According to the product manual, the invalid measurement data is judged, that is, data whose impedance values measured at frequencies of 5, 50, 100, and 200 kHz are not sequentially reduced or whose prediction index is greater than 1 will be excluded. Two companies were randomly selected to participate in the experiment, and no special randomization method was used. One retired recruit and 8 sets of invalid data were excluded. A total of 282 recruits were finally included in the study.

BIA Measurements

Body composition analysis was performed using the BodyStat QuadScan 4000 multifrequency BIA system. The test method is performed according to the manufacturer's instructions. Recruits are required to fast for solids and liquids for 4 to 5 hours before the test; do not engage in sports 12 hours before the test; do not drink alcohol or coffee 24 hours before the test.

This analysis instrument can measure at 5, 50, 100 and 200kHz to obtain four impedance values (IMPED5K, IMPED50K, IMPED100K, IMPED200K). TBW and fat-free mass (FFM) are predicted at a frequency of 50kHz. ECW is predicted at a frequency of 5kHz. The meanings of other parameters are as follows:

Prediction marker^{TM} =IMPED200K/IMPED5K

Nutritional index=ECW/TBW

3rd space water =TBW (predicted at 50kHz)-TBW (predicted at 200kHz)

TBW is the total amount of fluid in the body whether in cells, outside cells, in blood etc.

Body mass index (BMI)= Body weight / (Body height)2

BFMI= Body fat / (Body height)2

Fat-free mass index (FFMI)= (Body weight- Body fat) / (Body height)2

Training injury diagnosis

The diagnosis of training injuries is performed by the medics at the recruit training base according to the diagnostic criteria.

Statistical Analysis

Statistical analysis was performed using SPSS22.0. Continuous variables are shown as mean ± standard deviation. P <0.05 was considered statistically significant. The Shapiro-Wilk test was used to check whether the data conforms to a normal distribution. The mean comparison between the two groups of non-normally distributed data was performed using Wilcoxon rank sum test. ROC curves were performed to provide a basis for the independent variable assignment of logistic regression analysis. The independent relationship between the occurrence of lower limb training injuries and related factors was analyzed by binary multivariate logistic regression (forward: Wald method).

Results

General characteristics

A total of 282 recruits were included in the study. As shown in Table 1, after eight weeks of recruit training, a total of 71 recruits suffered training injuries. Among them, 66 cases of lower limb training injuries occurred, the incidence rate was 23.40%. The lower limb is the site where training injuries occur the most.

Table 1
Incidence of military training injuries for recruits at different locations

Injured body area	N	Incidence
Upper limb	5	1.77%
Lower limbs	66	23.40%
Trunk	4	1.42%
Head, face and other body areas	3	1.06%
total	71	25.18%

Data with a normal distribution were compared using T test; data with non-normal distribution were compared with Wilcoxon rank sum test. As shown in Table 2, compared with the lower limb uninjured group, the lean mass percentage ($P = 0.003$), TBW percentage ($P = 0.010$), ECW percentage ($P = 0.023$), ICW percentage ($P = 0.027$), 3rd space water ($P = 0.021$) and BMR/total weight ($P = 0.014$) of the lower limb injury group was higher. On the contrary, the body fat percentage ($P = 0.003$) and BFMI ($P = 0.005$) of the lower limb injury group was lower.

Table 2
Baseline characteristics of the participants (n = 282)

Characteristics	Sample (n = 282)	Lower limb training injury		Z/T	P
		No(n = 216)	Yes(n = 66)		
Age (year)	19.25 ± 1.340	19.24 ± 1.322	19.27 ± 1.409	-0.004*	0.996
Body height (m)	1.7081 ± 0.05123	1.7080 ± 0.05116	1.7085 ± 0.05184	-0.187*	0.852
Body weight (Kg)	62.076 ± 8.0957	62.302 ± 8.2555	61.333 ± 7.5617	-0.819*	0.413
BMI	21.260 ± 2.4741	21.337 ± 2.5017	21.008 ± 2.3829	-0.911*	0.362
Body fat percentage (%)	9.127 ± 3.5397	9.474 ± 3.6408	7.991 ± 2.9343	3.022	0.003
Lean mass percentage (%)	90.873 ± 3.5397	90.526 ± 3.6408	92.009 ± 2.9343	-3.022	0.003
TBW percentage (%)	66.599 ± 4.7623	66.195 ± 4.8379	67.921 ± 4.2787	-2.604	0.010
Prediction marker™	0.79072 ± 0.027715	0.79160 ± 0.026421	0.78785 ± 0.031634	-0.153*	0.879
Nutrition index	0.4349 ± 0.00861	0.4350 ± 0.00852	0.4345 ± 0.00898	-0.471*	0.638
Body cell mass (BCM)	32.201 ± 2.8967	32.151 ± 2.9701	32.364 ± 2.6569	-0.891*	0.373
ECW percentage (%)	28.139 ± 1.9689	27.992 ± 2.0164	28.621 ± 1.7326	-2.289	0.023
ICW percentage (%)	36.528 ± 2.2394	36.338 ± 2.1901	37.148 ± 2.3030	-2.217*	0.027
3rd space water	1.172 ± 0.6501	1.132 ± 0.6879	1.303 ± 0.4889	-2.303*	0.021
BMR	1750.59 ± 180.002	1750.84 ± 183.200	1749.79 ± 170.460	-0.057*	0.955
BMR/Total weight	28.305 ± 1.1576	28.210 ± 1.1836	28.615 ± 1.0156	-2.469*	0.014
Average daily calorie requirement	2966.30 ± 312.333	2968.60 ± 316.762	2958.76 ± 299.601	-0.325*	0.745
Phase angle	6.158 ± 0.8237	6.151 ± 0.8034	6.180 ± 0.8931	-0.500*	0.617
BFMI	1.991 ± 0.9539	2.075 ± 0.9815	1.717 ± 0.8049	-2.787*	0.005

*: Non-normal distribution.

Characteristics	Sample (n = 282)	Lower limb training injury		Z/T	P
		No(n = 216)	Yes(n = 66)		
FFMI	19.271 ± 1.8647	19.264 ± 1.8742	19.295 ± 1.8471	-0.063*	0.950
*: Non-normal distribution.					

Body Composition Roc Curve

We continued to make ROC curves for the above 8 indicators with statistical differences. The purpose is to observe the accuracy of these indicators as predictors of the occurrence of lower limb training injuries, and at the same time to provide a basis for the independent variable assignment of subsequent logistic regression analysis.

As shown in Fig. 1 and Table 3, the area under the curve (AUC) of the 8 indicators were statistically significant ($P < 0.05$). However, the AUC is not large, indicating that the prediction effect is not very good. The most sensitive indicator is BFMI; the most specific indicator is ICW percentage.

Table 3
Areas under curve (AUC) and cutoff points of body composition

Index	AUC	95%CI	p-Value	cutoff point	Sensitivity	Specificity
Body fat percentage (%)	0.625	0.551 ~ 0.699	0.002	≤ 8.750	0.652	0.579
Lean mass percentage (%)	0.625	0.551 ~ 0.699	0.002	> 91.250	0.652	0.579
TBW percentage (%)	0.600	0.525 ~ 0.675	0.014	> 65.350	0.803	0.421
ECW percentage (%)	0.590	0.515 ~ 0.665	0.027	> 27.350	0.803	0.375
ICW percentage (%)	0.590	0.511 ~ 0.670	0.027	> 37.950	0.348	0.810
3rd space water	0.594	0.519 ~ 0.668	0.022	> 0.950	0.864	0.347
BMR/Total weight	0.600	0.525 ~ 0.676	0.014	> 28.550	0.606	0.583
BFMI	0.613	0.539 ~ 0.688	0.005	≤ 2.450	0.894	0.282

Risk Factors Of Lower Limb Injuries

We continue to perform multivariate logistic regression analysis on the above seven indicators. Assignment is based on the cutoff point of the ROC curve, which is showed in Table 4. As shown in Table 5, the results of multivariate logistic regression analysis showed that TBW percentage > 65.350% (P = 0.050, OR = 2.085) and 3rd space water > 0.950 (P = 0.045, OR = 2.342) were independent risk factors for lower limb injuries.

Table 4
Assignment table

Index	Assignment
Body fat percentage (%)	0= “body fat percentage ≤ 8.750%”
	1= “body fat percentage > 8.750%”
Lean mass percentage (%)	0= “lean mass percentage ≤ 91.250%”
	1= “lean mass percentage > 91.250%”
TBW percentage (%)	0= “TBW percentage ≤ 65.350%”
	1= “TBW percentage > 65.350%”
ECW percentage (%)	0= “ECW percentage ≤ 27.350%”
	1= “ECW percentage > 27.350%”
ICW percentage (%)	0= “ICW percentage ≤ 37.950%”
	1= “ICW percentage > 37.950%”
3rd space water	0= “3rd space water percentage ≤ 0.950”
	1= “3rd space water percentage > 0.950”
BMR/Total weight	0= “BMR/ Total weight ≤ 28.550”
	1= “BMR/ Total weight > 28.550”
BFMI	0= “BFMI ≤ 2.450”
	1= “BFMI > 2.450”

Table 5
Multivariate logistic regression analysis of lower limb injuries

Index	β	SE	Wald	OR	95%CI	P-Value
TBW percentage (%)	0.735	0.374	3.857	2.085	1.002 ~ 4.341	0.050
3rd space water	0.851	0.425	4.004	2.342	1.018 ~ 5.390	0.045
CI, confidence interval;						

Discussion

According to report, the BMI of US recruits in 2002 was 24.53 ± 3.56 Kg / m^2, which was increased to 24.94 ± 3.84 Kg / m^2 in 2006 [3]. The BMI of recruits included in this survey is 21.278 ± 2.4699 Kg / m^2. Compared with the US recruits, the BMI of our recruits is lower. This may reflect the differences between China and the United States in terms of race, diet, and national conditions.

The Bodystat official website gives a male (30 years old) body fat percentage standard of 15–20%[18]. Considering that the 20 and 30 years olds are often grouped into the same group when the fat percentage is counted[19, 20], the above standards have a certain degree of reference significance. The body fat percentage of recruits included in this survey is 9.344 ± 3.9142%, which is significantly lower than the standard value of 15–20%. And the body fat percentage of the lower limb injured group was lower than that of lower limb uninjured group (7.991 ± 2.9343%vs 9.743 ± 4.0797%, p = 0.001). Combined with the lower BMI of our army's recruits, we speculate that our army's recruits have insufficient body fat percentage. Subcutaneous fat reduces the effects of mechanical forces on muscles and bones[21]. Therefore, recruits with a low body fat percentage are more vulnerable.

Since most of the body water is contained in the Lean Body Mass, the body water percentage will increase with a loss of fat weight and a gain in lean tissue[18]. The TBW standard provided by Bodystat's official website is 55–65% of body weight[18]. Multivariate logistic regression analysis showed that TBW percentage > 65.35% was an independent risk factor for lower limb training injuries. The water content of various tissues and organs of the human body is different, the water content of adipose tissue is 10%, and the water content of bones is 22%[22]. The high TBW on the one hand reflects the low body fat percentage, and its impact on training injuries has been discussed previously. On the other hand, high TBW may also indicate less bone content. Exercise and training increase bone strength, which helps reduce the risk of injury[23, 24]. Therefore, low bone mass may affect bone strength and further increase the possibility of training injuries.

Conclusions

TBW percentage > 65.35% and 3rd space water > 0.950 were independent risk factors for lower limb injuries. These recruits need to be paid more attention during training.

Abbreviations

BFMI
Body fat mass index
BIA
Bio-impedance
BMI
Body mass index
BMR
Basal metabolic rate
CI
confidence interval
ECW
Extracellular water
FFM
Far-free mass
FFMI
Fat-free mass index
ICW
Intracellular water
OR
Odds ratio
ROC
Receiver operator characteristic
TBW
Total body water

Declarations

- Ethics approval and consent to participate

The protocol for this study has been approved by the Ethics Committee of the Center for Specialized Medicine of the Army Medical University

- Consent for publication

Not applicable

- Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

- Competing interests

The authors declare that they have no competing interests

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- Authors' contributions

Z.Ni and X.Du designed the study and supervised the project. J.Ouyang, J.Yang and W.Jiang conducted the study. B.Li, K.Jin, L.Chen, X.Luo and J.Chang helped with data collection. T.Meng and Y.Hu helped with data analysis. Q.Tan, L.Kuang, Y.Xie, M.Liu, M.He and H.Chen helped with data interpretation. J.Ouyang and Z.Ni drafted the manuscript. L.Chen, and X.Du revised the manuscript. All authors contributed in approving the final version of manuscript.

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Not applicable

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Figures

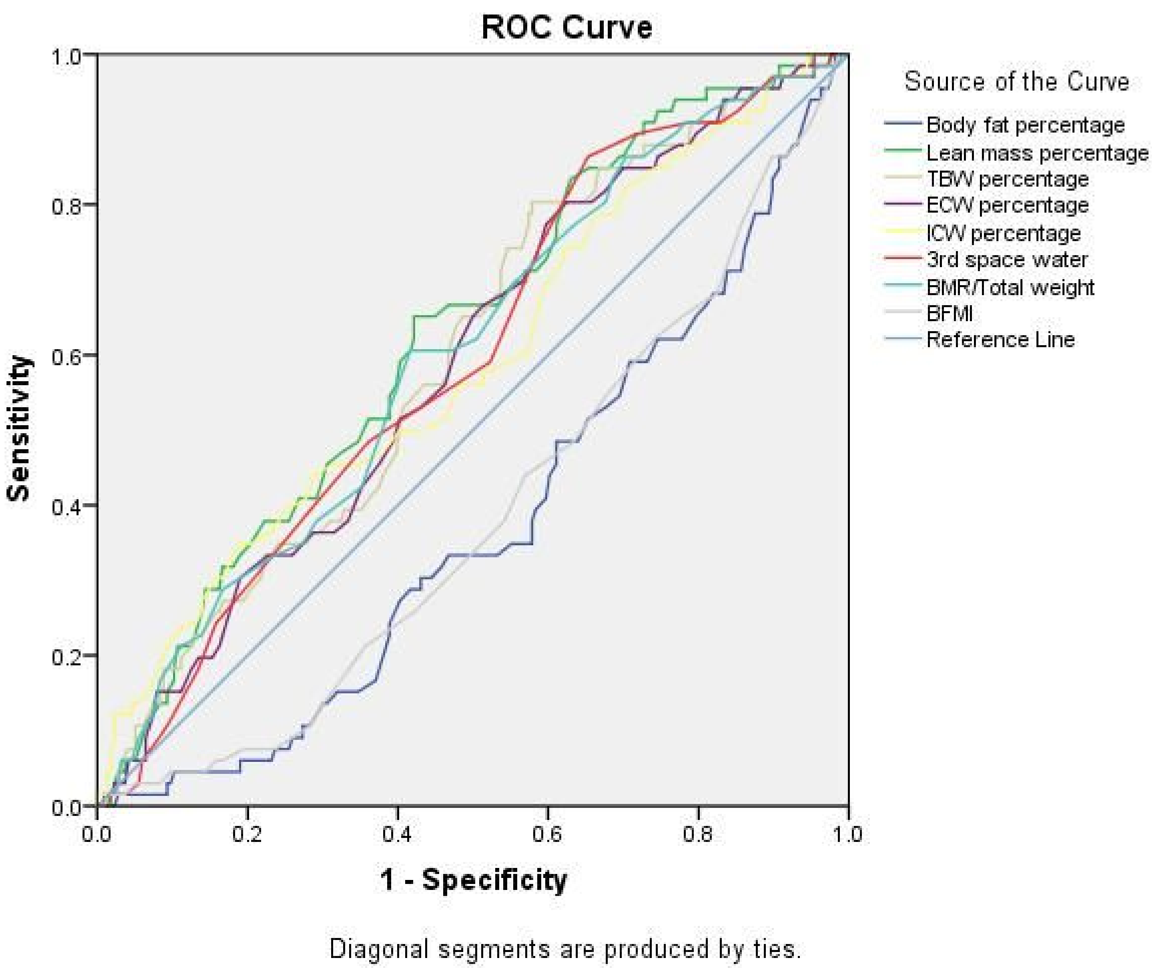

Figure 1

ROC curves of body composition