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VALIDITY AND RELIABILITY OF THE WEARABLE BIOELECTRICAL IMPEDANCE MEASURING DEVICE*

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ABSTRACT

Assessing and monitoring body composition is important for health. It is believed that in the future, wearable devices measuring the body composition, will be more common. The purpose of this study is to compare a wearable bioelectrical impedance measuring device, designed as a band, with a laboratory type of bioelectrical impedance device in order to investigate its reliability and validity. A total of 322 healthy people, 199 men, and 123 women participated in the study. The participants' body compositions were measured with the laboratory type of bioelectrical impedance device and recorded. Following these measurements, participants' body compositions were measured three times with the wearable bioelectrical impedance measuring device and data were recorded. The results of the measurements by both the laboratory type device and the wearable measuring device demonstrated a very high degree of correlations with each other. There were no significant differences between two devices' fat mass measurements in men, in women and in the whole group. When muscle mass data were evaluated, there were no significant differences between two devices' measurements in men and in the whole group, but there was a significant difference in women (p <.001). When wearable measuring device was compared with laboratory type of bioelectrical impedance device, fat mass measurement results were valid. However, in muscle mass measurements, there was a difference in women. When the wearable bioelectrical impedance measuring device's reliability was evaluated, it was demonstrated that the device yielded valid results. Therefore, it is concluded that the device will be useful for self-monitoring the body composition.
Keywords: Body Composition, ideal body weight, wearable electronic devices

GİYİLEBİLİR BİOELEKTRİK İMPEDANS ÖLÇÜM CİHAZININ GEÇERLİLİK VE GÜVENİRLİĞİNİN ARAŞTIRILMASI

ÖZET

Vücut kompozisyonun değerlendirilmesi ve izlenmesi sağlık açısından önemlidir. Gelecekte vücut kompozisyonunu ölçen ve takip eden cihazların daha yaygın kullanılacağına inanılmaktadır. Bu çalışmanın amacı bant olarak tasarlanan giyilebilir biyoelektrik empedans ölçüm cihazının, güvenilirliğini ve geçerliliğini araştırmak amacıyla laboratuvar tipi biyoelektrik empedans cihazı ile karşılaştırmaktır. Bu çalışma tekrarlanan ölçümlerden oluşan bir laboratuvar çalışmasıdır. Çalışmaya 199 erkek, 123 kadın toplamda 322 sağlıklı kişi katılmıştır. Katılımcıların vücut kompozisyonları laboratuvar tipi biyoelektrik empedans cihazı ile ölçülerek kaydedildi. Daha sonra katılımcıların vücut kompozisyonları giyilebilir biyoelektrik empedans cihazı ile üç kez ölçülmüş ve veriler kaydedilmiştir. Hem laboratuvar tipi cihaz hem de giyilebilir ölçüm cihazı ile yapılan ölçümlerin sonuçları birbiriyle çok yüksek derecede korelasyon göstermiştir. Erkeklerde, kadınlarda ve tüm grupta iki cihazın yağ kütle ölçümleri arasında anlamlı fark bulunmamıştır. Kas kütlesi verileri değerlendirildiğinde, erkeklerde ve tüm grupta iki cihazın ölçümleri arasında anlamlı bir fark bulunmazken, kadınlarda anlamlı bir fark görülmüştür (p <0,001). Giyilebilir ölçüm cihazı, laboratuvar tipi biyoelektrik empedans cihazı ile karşılaştırıldığında, yağ kütlesi ölçümleri geçerli sonuçlar vermiştir. Kas kütlesi ölçümlerinde ise, sadece kadınların ölçümleri arasında bir farklılık bulunmuştur. Giyilebilir biyoelektrik empedans ölçüm cihazları güvenilirliği değerlendirildiğinde, cihazın güvenilir sonuçlar verdiği görülmüştür. Bu nedenle, cihazın vücut kompozisyonunu ölçme ve takip etme açısından faydalı olacağı sonucuna varılmıştır.
Anahtar Kelimeler: Giyilebilir elektronik cihazlar, ideal vücut ağırlığı, vücut kompozisyonu.

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*Giyilebilir Bioelektrik Impedans Ölçüm Cihazının Geçerlilik ve Güvenirliğinin Araştırılması adlı tezden hazırlanmıştır.

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INTRODUCTION

The body composition is defined as the proportions of either fat or lean tissue composites of the body. Assessing and monitoring the body composition is essential for health. It is reported that increasing physical fitness, which is an important component of the health, decreases the risk of coronary heart diseases, whereas, high Body Mass Index (BMI) values increase the risks of coronary artery diseases, hypertension, hyperlipidemia and diabetes [1, 2]. Also, body composition is firmly associated with sport performance. The increase of lean body mass is an essential indicator of performance, increases in some sports requiring strength, speed, and agility [3].

A variety of measurement methods can be used in determining the body composition, such as Hydrostatic Weighing (HW), Air-Displacement Plethysmography (ADP), Bioelectrical Impedance Analysis (BIA), Dual Energy X-ray Absorptiometry (DEXA), Computed Tomography (CT), and Magnetic Resonance Imaging (MRI). These methods bear some superiorities as well as some inferiorities when compared with each other. Therefore, it is possible to decide on which method to use among a variety of options depending on the purpose for use, on the population to be used in, and on the required sensitivity of the measurement. Although there are many measurement methods, it is still maintained as a current debate in the presence of several publications of studies in the literature on new products and methods [4-7].

BIA method is an economical and non-interventional method for determining the body composition. BIA does not require high-level technical skills and is safer and more comfortable for the participants compared to the other methods such as HW, ADP and DEXA. Although the calculation errors are high in obese individuals, the BIA method can measure more effectively the body composition in the overweight group [8].

The WBID measures the fat and muscle mass as it is calculated by BIA. In addition, in order to promote physical activity, the device contains a three-axial accelerometer measuring physical activity and warning individuals whether daily targets are met.

Conveying the need of exercise for a healthy life to a wide variety of people by education and mass media has rendered health related sports activities a part of an active lifestyle. In scientific publications, exercise recommendations are determined by a variety of parameters such as the number of steps, or the degree and the content of the exercises [9].

The demand for monitoring to Body Composition for the exercise prescriptions importance of this kind of wearable technologies increase day by day [10-13].

Recording the data, collected by these methods, and making them available will be motivating and inspiring for physical activities. Wearable products will make monitoring possible during the daily activities at schools, offices, in the field and in various other environments.

The objective of this study is to determine the validity and the reliability of a wearable bioelectrical impedance device (WBID), which is one of the wearable technology products designed as a band, by comparing it with the laboratory type bioelectrical impedance device (LTBID), which had already been studied for validity and reliability by DEXA and Skinfold methods [14].

MATERIAL AND METHODS

Participants

Male and female volunteers between ages of 12-65 years were included in the study. Reliability analysis of three measurements has been conducted with intra-class correlation (ICC). Then, the sample size was calculated to be at least 73 for a strength of 0.90 [15,16]. The exclusion criteria were defined as the conditions where the impedance method cannot be used, the individuals with implanted defibrillators or pacemakers, and pregnant women as participants. A total of 322 individuals, comprised of 199 male and 123 female volunteers between ages of 12-65 years were included in the study.

Experimental protocol

The participants were informed of the study procedure and measurements. Then, the signed consent forms were collected from the consenting individuals. The measurements were performed in the exercise physiology laboratories. The Ethical Committee of the University approved this study.

The body composition analysis of the participants was made by the LTBID with a trademark of InBody 720 (Body Composition Analyzers, South Korea). The heights of the participants were measured on bare feet by the Stadiometer (G-Tech International, Korea).

Following this procedure, the participants wore the Wearable InBody body composition analyzer band (South Korea), and their other body composition data were measured.

The body composition analyses of the participants were performed after a 2-hour period of fasting as participants were not wearing any metal devices, in alignment with the instructions of the manufacturer company (Biospace, Inbody 720, Seul, South Korea).

When the body composition measurements were performed by the wearable band, the individuals stood with their shoulders and elbows in flexion and with their thumbs and the index fingers of their left hands placed on the electrodes on the band (Figure 1). The measurements were performed three times in total with 2-minute intervals.

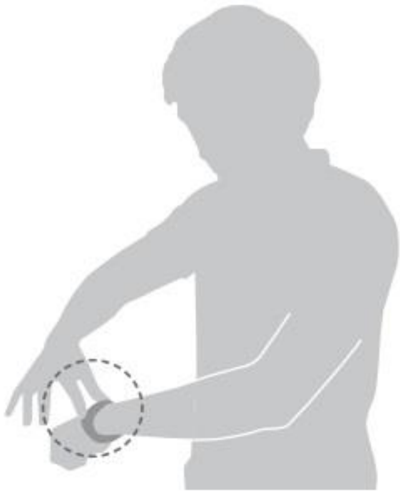

Figure1. Inbody Band Measurement Position [17]

Data analysis and statistics

The sample size estimations and the power calculations were performed by NCSS PASS (v13, NCSS, LLC 1981, Utah-USA) and the inferential statistical evaluations were performed by SPSS (21.0, Chicago, IL). Pearson correlation was used to examined the relationship between the WBID with the LTBID, variations between the measurements were evaluated by ANOVA with Tukey test used as post-hoc. To demonstrate the alignment of the measurements between the two devices, Bland Altman graphics were drawn, and the alignment limits were determined for a 95% confidence interval. The reliability was assessed by ICC.

RESULTS

The anthropometric measurement results and the descriptive data of the participants obtained from the information collected are presented in Table 1.

Table 1. Male, Female and All Participants' Anthropometric Measurements

	Male (n=199)		**Female (n=123)**		**All Participants (n=322)**	
	x̄	**SD±**	**x̄**	**SD±**	**x̄**	**SD±**
Age (year)	22.4	±9.9	28.4	±12.0	24.7	±11.1
Height (cm)	176.1	±8.0	161.8	±6.2	170.6	±10.1
Weight (kg)	74.5	±14.4	60.7	±9.4	69.2	±14.3
BMI (kg/m^2)	23.9	±3.8	23.2	±3.6	23.6	±3.8

x̄ = Mean **S.D.=** Standard Deviation BMI = Body Mass Index

When the body fat compositions of the participants were measured by the LTBID, men had a mean of 14.72 kg and women had a mean of 18.76 kg of fat mass and the mean fat mass of the whole participant group was 16.27 kg (Table 2). When the same measurements were performed by the WBID in the same participants, the results of the three consecutive fat mass measurements in men were 15.45 kg, 15.26 kg and 15.24 kg. When the results of the fat mass measurements obtained by WBID and by the LTBID were compared, a very strong correlation was demonstrated (r= .954, .958 and .958; respectively, Table 2). The three consecutive measurements in women yielded fat mass results of 18.59 kg, 18.51 kg, and 18.48 kg, respectively. When the results of the fat mass measurements obtained by the WBID and by the LTBID were compared, a very strong correlation was demonstrated (r=.968, .969 and .970, Table 2). The three consecutive measurements in the overall group resulted in fat masses of 16.65 kg, 16.50 kg and 16.47 kg. When the results of the fat mass measurements obtained by the WBID and by the LTBID were compared, there was a very strong correlation (r= .960, .962 and .962; respectively, Table 2). When muscle masses of the participants were measured by the LTBID, men had a mean of 33.70 kg and women had a mean of 22.88 kg of muscle mass and the mean muscle mass of the whole participants were 29.57 kg. Then, the same measurements were performed by the WBID in the same participants; the results of the three consecutive measurements in men were 33.68 kg, 33.78 kg, and 33.82 kg. When the results of the muscle mass measurements obtained by the WBID and by the LTBID were compared, a very strong correlation was demonstrated (r= .953, .958 and .958, respectively, Table 2). The three-consecutive muscle mass measurement results in women were 24.09 kg, 24.16 kg, and 24.18 kg, respectively. When the results of the muscle mass measurements obtained by the WBID and by the LTBID were compared, there was a very strong correlation (r= .923, .924 and .927, respectively, Table 2). The measurements in the overall group yielded muscle mass values of 30.02 kg, 30.10 kg and 30.14 kg. When the results of the muscle mass measurements obtained by the WBID and by LTBID were compared, a very strong correlation was demonstrated (r= .979, .979 and .979, respectively, Table 3).

When the differences between the groups were evaluated by ANOVA, no significant differences were identified between the LTBID and the WBID in terms of the mean values of fat mass measurements in men, in women and the overall participant group. When the same evaluation was performed for the muscle mass, it was demonstrated that the mean values either measured by the LTBID or by the WBID, performed in men and the overall group, were not significantly different. However, when the muscle mass measurement results of the women were studied, it was detected that the measured values by the WBID were higher compared to those by the LTBID F (3,488) = 6.268, (p<.001).

When the measured values of fat and muscle masses of men, women and the fat and muscle mass values in the overall group were evaluated by Bland Altman analysis, it was observed that all measured values were aligned for all parameters (Figures 2 and 3).

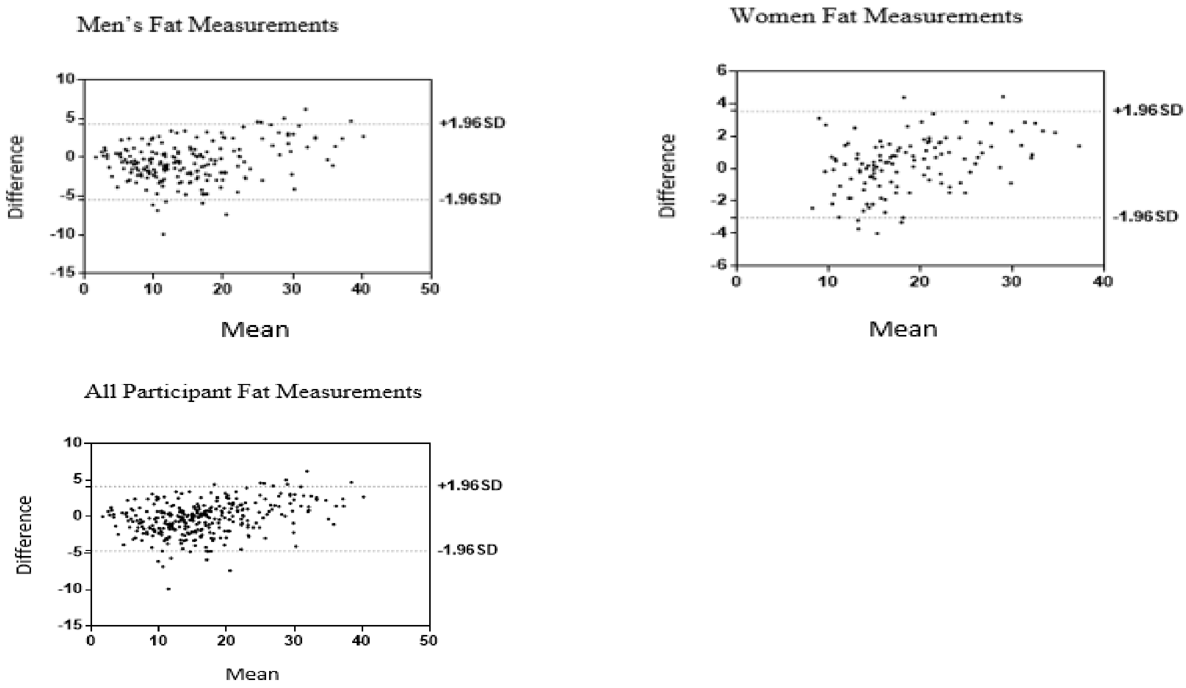

Figure 2. Bland Altman Graph of participants' fat measurements

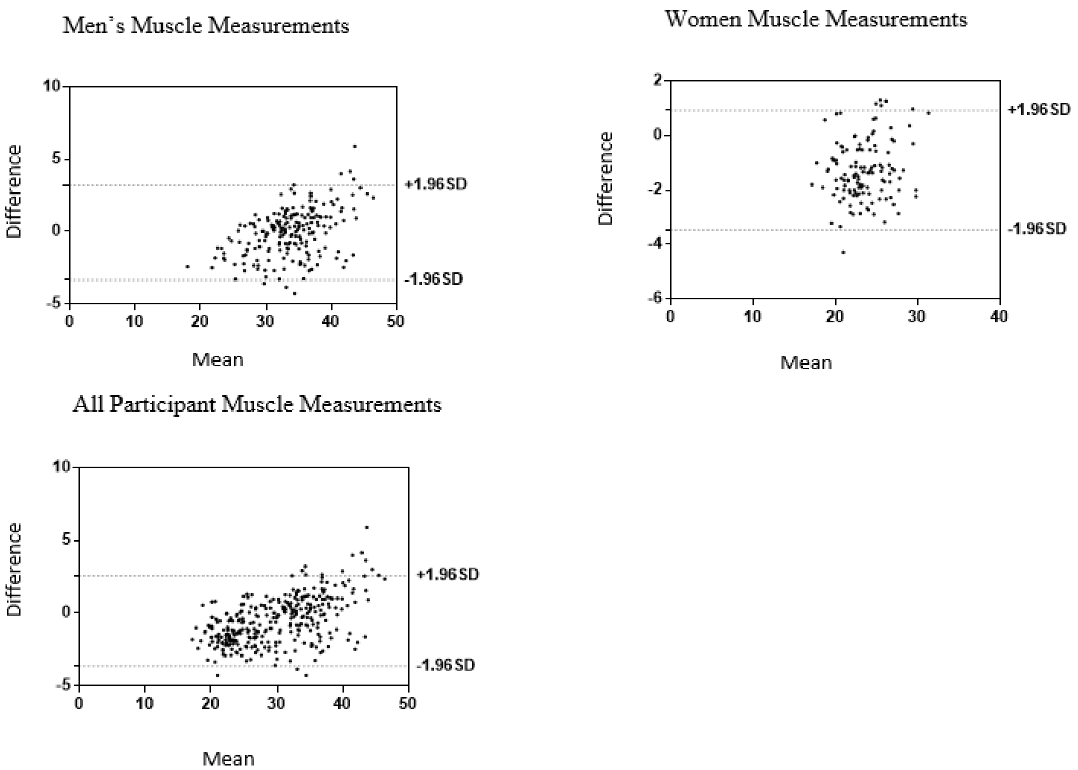

Figure 3. Bland Altman Graph of participants' muscle measurement

Table 2. Male, Female and All Participants' validity analysis of fat (kg) data

	LF		BF1				BF2				BF3						ANOVA	
	x̄	**S.E.**	**x̄**	**S.E.**	**r**	**P**	**x̄**	**S.E.**	**r**	**p**	**x̄**	**S.E.**	**r**	**p**	**p^{β}**	**ICC**	***F***	**p^{α}**
Male	14.72	0.61	15.45	0.55	.954	.0001	15.26	0.56	.958	.0001	15.24	0.56	.958	.0001	.0001	.999	.300	.826
Female	18.79	0.59	18.59	0.53	.968	.0001	18.51	0.53	.969	.0001	18.48	0.53	.970	.0001	.0001	.999	.061	.980
All Participants	16.27	0.45	16.65	0.40	.960	.0001	16.50	0.41	.962	.0001	16.47	0.41	.962	.0001	.0001	.999	.136	.938

x̄ = Mean **LF=** LTBID Fat Measurement **BF1=** 1.Fat Measurement WBID **BF2=** 2. Fat Measurement WBID **BF3=** 3. Fat Measurement WBID **S.E.=** Standard error **r=** Pearson Correlation between LTBID and WBID **p=** Significance of Correlation between LTBID and WBID **p^{β}=** ICC Significance **ICC=** Intraclass correlation between WBID measurements **p^{α} =** Significance of variance difference between groups (Anova) ***p***< .001

Table 3. Male, Female and All Participants' validity analysis of muscle (kg) data

	LM		BM1				BM2				BM3						ANOVA	
	x̄	**S.E.**	**x̄**	**S.E.**	**r**	**P**	**x̄**	**S.E.**	**r**	**p**	**x̄**	**S.E.**	**r**	**p**	**p^{β}**	**ICC**	***F***	**p^{α}**
Male	33.70	0.38	33.68	0.31	.953	.0001	33.78	0.33	.958	.0001	33.82	0.33	.958	.0001	.0001	.999	0.38	.990
Female	22.88	0.26	24.09	0.24	.923	.0001	24.15	0.24	.924	.0001	24.18	0.24	.927	.0001	.0001	.999	**6.268**	**.0001****
All Participants	29.57	0.39	30.02	0.34	.979	.0001	30.10	0.34	.979	.0001	30.14	0.34	.979	.0001	.0001	.999	.544	.652

x̄ = Mean **LM=** LTBID Muscle Measurement **BM1=** 1.Muscle Measurement WBID **BM2=** 2. Muscle Measurement WBID **BM3=** 3. Muscle Measurement WBID **S.E.=** Standard error **r=** Pearson Correlation between LTBID and WBID **p=** Significance of Correlation between LTBID and WBID **p^{β}=** ICC Significance **ICC=** Intraclass correlation between WBID measurements **p^{α} =** Significance of variance difference between groups (Anova) *******p*< .001 Difference between LTBID and WBID (Tukey Test)

DISCUSSION

This study investigated the validity and the reliability of the wearable bioelectrical impedance device, designed as a band. This is the first study on the wearable body composition devices.

When the WBID was compared with the LTBID method in terms of their measurements of fat mass, it yielded valid and reliable results in both sexes. As regards to the muscle mass measurements, although the validity was not detected in women, the results were reliable. In a previous study on 50 healthy volunteers, Maughan et al. measured the body fat mass by the HW, BIA and Skinfold methods, and compared these three methods with each other. The mean values were 20.5%, 21.8%, and 21.8% for the HW, Skinfold and BIA methods, respectively. Although the correlation between the Skinfold and HW method was .931, the correlation between the BIA and HW was .830, and the correlation between the Skinfold and BIA method was .842, the number of participants in this study was fairly low [18]. In our study, it was aimed to obtain a wider distribution by including participants with all variations of body compositions. When the results of both devices' measurements were compared, a very high level of correlation was demonstrated in terms of the fat mass. Biaggi et al. compared the measured values of the ADP, HW and BIA methods in a study with 47 healthy participants. The number of the participants in this study is very low compared to that of our study. The measured values of body fat percentages were 25.0 by the ADP method, 25.1 by the HW method, and 23.9 by the BIA method. It was reported that there were no differences detected between these results of fat percentage measurements [19].

When the measured values by the WBID were compared with those of the LTBID, the results were valid and reliable in terms of fat measurements in men, women and in the overall group, and a very high level of correlation was demonstrated among them as well. When the muscle mass values were studied, the WBID measurement values were found to be higher compared to those by the LTBID. However, when the measured values in men and in the overall group were studied, the muscle mass values were both valid and reliable with a very high level of correlation. It is reported in the literature that the regular monitoring of the body composition is an effective method in exercise or diet associated interventions and in monitoring the growth rates or the courses of diseases [20]. The ease of the usage of the wearable technologies, the fact that is economical, its reliability in terms of the measured values in both sexes, and its high levels of correlations both within its measured values and when compared with the other device enables this device usable. Therefore, it is considered that the wearable device can be used by individuals to monitor their body composition.

CONCLUSION

Although there are various methods to measure the body composition, it may be thought that these methods may not be suitable for individual usage due to the issues in their accessibility and difficulties of usage.

This is the first study conducted on the wearable bioelectrical impedance device. The ease of application of the wearable technologies and their accessibilities provide remarkable advantages over other devices. When the results of the study were evaluated, it was demonstrated that the wearable device provided valid and reliable results in both sexes in measuring the fat compositions. As regards to the measurements of the muscle mass, the results were reliable; but they did not demonstrate validity in women. This device will enable individuals to evaluate and monitor their body compositions as well as contribute to the formation of a databank by collecting all the recorded data at a single center using the software of the device. This databank may provide data for the future epidemiological studies [21].

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Conflict of interest

There is no conflict of interest.

Limitations

The data collected in this study could not be compared to the data obtained by the other methods including air displacement plethysmography, hydrostatic weighing, and DEXA.

The limited number of studies conducted in this area introduced another limitation to evaluate and discuss the results of this study.

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