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Utilizing Bioelectrical Impedance Analysis and Smart Fitness Devices in Assessing Physical Fitness and Body Composition Among Elderly Individuals

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ABSTRACT

Background: The global population is experiencing a significant and remarkable increase in the number and proportion of elderly individuals presenting unique challenges. This study aims to evaluate physical fitness levels among older adults, employing validated assessment tools to support evidence-based planning and the development of targeted interventions in geriatric health.

Methods: This cross-sectional study involved 210 older adults aged 60 and above, selected through cluster random sampling. Data were collected using a combination of objective and self-reported measures, including smart fitness devices (mobile fitness trackers) for real-time activity monitoring. Anthropometric assessments and bioelectrical impedance analysis (BIA) were used to evaluate body composition. The International Physical Activity Questionnaire (IPAQ) and Senior Fitness Test (SFT) assessed physical activity levels and functional fitness, with additional data gathered from structured interviews. Ethical approval and informed consent were obtained. Data analysis was performed using

SPSS version 27, with descriptive statistics and Pearson's correlation coefficient to examine the relationships between physical fitness and body composition.

Results: A significant negative correlation was identified between body fat percentage and various physical fitness parameters. Specifically, body fat percentage was negatively correlated with lower body strength (r= -0.25, p<0.001), upper body strength (r= -0.22, p<0.001), and lower body flexibility (r= -0.22, p<0.001). These results suggest that increased body fat is associated with diminished strength and flexibility in older adults.

Conclusions: Our findings demonstrate that body composition, particularly elevated body fat percentage and BMI, negatively impacts physical capabilities such as strength, flexibility, and cardiovascular health in older adults. The observed decline in flexibility and cardiovascular capacity underscores the need for targeted interventions, including stretching and structured high-intensity exercise programs, to improve strength and balance and reduce fall risks. Tailored exercise strategies are essential to enhance body composition, optimize physical fitness, and improve overall health and quality of life in the elderly.

K E Y W O R D S

Body Composition, Cardiovascular Health, Flexibility, Elderly Population, Muscular Strength, Physical Fitness.

Introduction

The world is experiencing an remarkable rise in the number and proportion of elderly individuals [1, 2]. While this phenomenon has already been encountered in developed nations, the United Nations (UN) predicts that the most rapid aging processes will take place in developing countries [2]. Among these, Iran stands out as a country facing significant demographic shifts. By 2050, the proportion of Iranians aged 60 and older is projected to rise dramatically from 10% in 2016 to over 33% [3]. Similarly, on a global scale, the population aged 64 and older is growing faster than any other age group [4]. According to the 2019 World Population Prospects, older individuals will account for 16% of the global population by 2050 [5]. This shift underscores the urgent need to address the societal challenges associated with aging, particularly in ensuring a high quality of life for the elderly [4]. Critical aspects of this include providing effective healthcare and promoting active aging, which focuses on maintaining older adults' ability to perform daily activities independently for as long as possible [6].

One of the key changes that occurs with aging is the alteration in body composition [7]. Studies consistently show that aging is associated with a loss of muscle mass, a reduction in fat-free mass, and an increase in total fat mass [8]. These changes significantly affect the health and quality of life of older individuals, increasing their vulnerability to malnutrition and raising the risk of disability [9]. It is important to note that health risks in older adults cannot be fully assessed through traditional measures such as body fat percentage or distribution [10]. Aging leads to a decline in several non-fat components of body composition, including muscle mass, bone density, extracellular fluid volume, and body cell mass [10]. These components play critical roles in influencing an individual's cognitive and physical performance, nutritional status, endocrine function, and overall quality of life [11, 12]. Moreover, disruptions in body composition can exacerbate comorbidities and diminish functional independence [13]. Tailored interventions, including targeted exercise regimens, nutritional supplementation, and, in some cases, hormone replacement or appetite-stimulating medications, may help address these complex patterns of "disordered body composition [7]."

Aging also brings physiological changes that profoundly impact overall health and well-being [14, 15]. Researchers have increasingly focused on understanding the interplay between physical fitness, body composition to exercise in older adults [16]. These factors collectively shape health outcomes in this age group. Physical fitness, defined as the ability to perform daily tasks with vigor and without excessive fatigue, is an essential component of healthy aging [17]. It also includes the energy reserves needed to enjoy leisure activities and handle emergencies [18]. Numerous studies have demonstrated the benefits of physical fitness in reducing the risk of chronic diseases, improving functional independence, and enhancing overall quality of life in older adults [19]. For example, regular physical activity has been shown to reduce the incidence of cardiovascular disease, diabetes, and cognitive decline, while also supporting mental health and longevity [16]. Body composition, particularly the balance between lean muscle mass and fat mass, undergoes significant changes with age [8]. Older adults tend to experience a decrease in lean muscle mass accompanied by an increase in fat mass, a phenomenon with profound implications for metabolic health and physical function [20]. These shifts highlight the importance of interventions that promote muscle retention and minimize excessive fat accumulation [21]. By combining exercise, proper nutrition, and other tailored strategies, older adults can maintain better health and functional independence as they age [22, 23].

In summary, the aging population presents a multifaceted challenge that requires a comprehensive understanding of the physiological, nutritional, and physical fitness aspects of aging [24]. Interventions aimed at promoting active aging and addressing changes in body composition are essential for improving the health outcomes and quality of life of older adults in the coming decades [25]. Despite evidence showing that physically active older adults experience lower morbidity and mortality rates compared to their inactive counterparts, over 60% of older adults do not engage in regular exercise [26]. This concerning statistic highlights the need to understand and promote physical activity among the elderly. While the terms physical activity and exercise are often used interchangeably, they represent distinct concepts. Physical activity refers to any bodily movement produced by skeletal muscles that increases energy expenditure [27]. In contrast, exercise is a subset of physical activity, characterized by planned, structured, and repetitive movements designed to improve or maintain physical fitness [27]. For instance, an individual may remain physically active by performing daily tasks such as walking or housework without engaging in structured exercise routines [28].

Current guidelines, including those from the Surgeon General, recommend 20 to 30 minutes of moderate-intensity physical activity on most days of the week, equating to approximately 1,000 kcal per week [29]. These guidelines are intentionally flexible to encourage broad participation in physical activity. However, studies have shown that scheduled and consistent exercise offers greater health benefits than sporadic, moderate-intensity physical activity throughout the day [30].

Recognizing this, the American College of Sports Medicine has updated its recommendations, advocating for more frequent and higher-intensity activities to maximize health outcomes [28]. Regular exercise has been identified as a critical strategy for preventing age-related disorders, such as cardiovascular disease, and for improving both physical and psychological well-being [31]. Exercise not only delays the aging process but also enhances vitality and overall health in older adults [32]. Participation in exercise programs has been linked to increased independence and a greater inclination toward social engagement, fostering a better quality of life in the elderly [33]. Additionally, exercise contributes to reductions in body fat percentage (BFP) and obesity, increased muscle strength, improved balance, decreased risk of falls, alleviation of muscle pain, and enhanced mental health [28].

Body composition plays a pivotal role in this equation, serving as both a determinant and a reflection of physical fitness and overall health. Proper management of body composition—characterized by a balanced ratio of fat mass to lean body mass—is associated with improved cardiovascular health and, consequently, a better quality of life [34]. Unfortunately, many elderly individuals suffer from critical illnesses such as hypertension, diabetes, cardiovascular disease, and musculoskeletal disorders, which are often exacerbated by poor body composition [35]. This underscores the importance of assessing body composition to establish optimal fitness levels and promote health in aging populations [7]. The relationship between physical fitness and body composition becomes even more critical in the context of developing countries like Iran [36]. While developed nations are equipped to address the challenges posed by aging populations, many developing countries remain underprepared [37]. This deficiency in preparedness exacerbates the multifaceted health, social, and economic burdens associated with demographic aging. The study locale offers a distinctive context for exploring these issues, as it represents a population on the threshold of substantial demographic transformation. The primary objective of this study is to conduct a comprehensive evaluation of the interrelationship between physical fitness and body composition among elderly individuals, thereby contributing valuable insights to mitigate the challenges posed by aging in the context of developing nations.[38].

The lack of appropriate facilities for leisure-time physical activity among the elderly underscores the widespread issue of sedentary and inactive lifestyles within this demographic. Consequently, it is essential for institutions responsible for the care of the elderly and disabled to shift their focus toward enhancing opportunities for leisure and physical activity. Given the increasing trend in the elderly population in Iran, the present study aims to assess the level of physical fitness among the elderly by introducing two critical tools for evaluating physical fitness. This can serve as a foundation for future planning and interventions in this area.

Material and Methods

The study targeted elderly individuals aged 60 years and above residing in Tabriz. Inclusion criteria required participants to be physically capable of completing fitness assessments, cognitively intact, and willing to provide informed consent. Participants with debilitating illnesses or conditions interfering with physical performance were excluded. A sample size of 210 individuals was determined using G*Power software, with parameters set to a significance level of 0.05, statistical power of 80%, and a medium effect size. Cluster random sampling was employed, selecting clusters based on geographic zones to ensure representativeness of the elderly population.

Data collection in this study utilized a combination of smart fitness devices, specifically a mobile fitness tracker (smartphone application combined with built-in sensors), and standardized, validated tools for comprehensive assessment. The mobile fitness tracker used in the study was capable of measuring key metrics such as physical activity levels, heart rate, and step count. The validity and reliability of smartphone-based fitness trackers have been supported by multiple studies. For example, research by Cadmus-Bertram et al. (2015) demonstrated that mobile fitness trackers are highly accurate in measuring daily step counts (validity = 0.96) and heart rate (validity = 0.94) when compared with gold-standard devices like pedometers and heart rate monitors . The reliability of these devices is also high, with intra-class correlations (ICC) ranging from 0.85 to 0.94 in measuring daily physical activity in diverse populations, including older adults [39].

Physical activity levels were measured using the International Physical Activity Questionnaire (IPAQ), adapted for the local context, alongside real-time data from the mobile fitness tracker to offer an objective measurement of activity patterns. The IPAQ has been widely validated for elderly populations and has demonstrated excellent reliability (Cronbach's alpha = 0.88) and good construct validity (r = 0.76) in measuring physical activity levels among older adults [40]. Functional fitness was assessed using the Modified Senior Fitness Test (SFT), with mobile fitness technology used to monitor movement and provide feedback on performance metrics such as speed, strength, and endurance. This test battery included assessments of lower body strength (chair stand test), upper body strength (arm curl test), aerobic endurance (six-minute walk test), cardiovascular endurance (two-minute step test), lower body flexibility (sit-and-reach test), upper body flexibility (back scratch test), and agility and dynamic balance (8-foot up-and-go test), all enhanced by data captured from the fitness tracker.

Body composition was analyzed using Bioelectrical Impedance Analysis (BIA) with integration of smart BIA technology under standardized conditions to provide estimates of body fat percentage and lean body mass. BIA has been validated for use in older populations and has shown high accuracy (r = 0.95) when compared to gold-standard methods like DXA. The smart BIA devices used in this study have demonstrated high reliability (ICC = 0.92) and validity (r = 0.98) for estimating body fat and lean mass [56]. In addition, Waist-to-Hip Ratio (WHR) was measured using calibrated non-elastic tape, and other anthropometric measurements, including height and weight, were recorded with calibrated digital scales and stadiometers.

Ethical approval for the study was obtained from the university's Research Ethics Committee. Written informed consent was collected from all participants, ensuring adherence to ethical guidelines. Participant confidentiality was maintained through anonymized data handling and secure storage protocols.

Data analysis was performed using SPSS software (version 27). Descriptive statistics, including means and standard deviations, were used to summarize the data. Normality tests Shapiro-Wilk were conducted to evaluate the data distribution. Additionally, Pearson correlation analysis was used to examine relationships between physical fitness components, body composition indices, and related variables.

Results

The descriptive statistics for the measured physical and activity indicators are presented in Table1. These results provide a comprehensive overview of the physical characteristics and activity levels of the individual study.

Table 1. Descriptive statistics of measured indicators

Physical Indicators	**Physical Indicators**	**Measurement Indicators**	**Minimum**	**Maximum**	**Mean**
	Height	(cm)	145	184	166.77
	Weight	(kg)	50	127	77.47
	Lean Body Mass	(kg)	35.8	81.6	55.35
	Body Mass Index (BMI)	(kg/m^2)	18.5	40	28.38
	Body Fat Percentage	(%)	11.63	50.2	29.4
	Waist-Hip Ratio	Ratio	0.7	1.16	0.95
Physical Activity	Physical Activity	Physical Activity Level	0	1	0.48

The descriptive statistics for the objective physical fitness measurements are presented in Table 2. These findings underline the diversity in physical fitness levels among the study participants.

Table 2. Descriptive statistics for objective measurement of physical fitness

Physical Fitness Objective Measurement Items	**Minimum**	**Maximum**	**Mean**	**Standard Deviation**
Item 1: Lower Body Strength	5	34.00	15.76	6.29
Item 2: Upper Body Strength	9.19	43.00	22.67	6.10
Item 3: Cardiovascular Fitness	42.00	110.00	61.03	23.01
Item 4: Lower Body Flexibility	51.00	54.00	2.71	10.51
Item 5: Upper Body Flexibility	50.00	32.00	13.43	12.88
Item 6: Agility and Dynamic Balance (Time-based)	3.50	15.00	6.56	1.75

The Pearson correlation analysis revealed several noteworthy relationships between physical fitness parameters and other variables, as detailed in Table 3. A significant positive correlation was observed between Physical Activity Level and Upper Body Flexibility ($r = 0.13$, $p = 0.03$), as well as with Agility and Dynamic Balance ($r = 0.16$, $p = 0.01$). Conversely, Lean Body Mass showed a significant negative correlation with Lower Body Flexibility ($r = -0.15$, $p = 0.01$). Furthermore, Body Fat Percentage demonstrated significant negative correlations with multiple physical fitness measures, including Lower Body Strength (r = -0.25, p < 0.001), Upper Body Strength (r = -0.22, p < 0.001), and Lower Body Flexibility (r = -0.22, p < 0.001). Body Mass Index (BMI) also exhibited significant negative associations with Lower Body Strength (r = -0.17, p = 0.007), Upper Body Strength (r = -0.16, p = 0.01), and Cardiovascular Fitness (r = -0.18, p = 0.003). Additionally, Waist-Hip Ratio was significantly negatively correlated with Upper Body Flexibility (r = -0.18, p = 0.003).

Table 3. Correlation between physical indicators and physical activity levels with objective physical fitness items

Measurement Items	Pearson Correlation Coefficient	Item 1: Lower Body Strength	Item 2: Upper Body Strength	Item 3: Cardiovascular Fitness	Item 4: Lower Body Flexibility	Item 5: Upper Body Flexibility	Item 6: Agility and Dynamic Balance (Time-based)
Physical Activity Level	Pearson Correlation	0.11	0.01	0.07	-0.08	0.13*	0.16**
	Significance (p)	0.07	0.77	0.22	0.17	0.03	0.01
Lean Body Mass	Pearson Correlation	0.002	0.08	-0.03	-0.15*	-0.11	0.05
	Significance (p)	0.97	0.2	0.64	0.01	0.07	0.38
Body Fat Percentage	Pearson Correlation	-0.25**	-0.22**	-0.11	-0.22**	-0.02	0.15*
	Significance (p)	0.0001	0.0001	0.07	0.0001	0.65	0.01
Body Mass Index (BMI)	Pearson Correlation	-0.17**	-0.16*	-0.18**	0.07	-0.05	0.16*
	Significance (p)	0.007	0.01	0.003	0.21	0.36	0.01
Waist-Hip Ratio	Pearson Correlation	0.02	0.1	0	-0.05	-0.18**	-0.05
	Significance (p)	0.7	0.1	0.9	0.4	0.003	0.43

*$p \leq 0.05$, **$p \leq 0.01$

Discussion

The study aimed to investigate A Comprehensive Assessment of Physical Fitness and Its Relationship with Body Composition Among the Elderly. Our results offer valuable insights into the interplay between body composition and physical fitness in the elderly, emphasizing key aspects such as flexibility, strength, and cardiovascular fitness.

The descriptive analysis revealed variability in body composition and physical fitness among participants. Indicators like Body Mass Index (BMI) and Body Fat Percentage (BFP) were negatively correlated with physical fitness measures, such as upper and lower body strength, aligning with previous studies that highlight the adverse effects of higher adiposity on muscle performance and cardiovascular endurance [41]. For instance, research has consistently shown that obesity is linked to diminished physical function and increased frailty risk in older adults [42], corroborating our findings regarding BMI and BFP's negative impact on fitness measures such as lower body strength and flexibility.

Flexibility assessments revealed notable deficits in both lower and upper body flexibility in the study population. This is consistent with research demonstrating age-related declines in joint mobility and elasticity [43], which can impair daily functional activities [44]. Several studies emphasize that interventions incorporating multiarticular and dynamic stretching exercises can significantly improve flexibility in older populations, suggesting a potential area of focus for enhancing functional capacity in our study group [45, 46].

Cardiovascular fitness, as measured in our study, showed substantial variation and was negatively associated with higher BMI. These findings align with results from Ramirez-Campillo et al., where interventions involving high-speed and high-intensity functional training improved cardiorespiratory capacity [47]. This underscores the potential for targeted exercise programs to mitigate age-related declines in cardiovascular health, especially for individuals with higher BMI [48].

Dynamic balance and agility are critical for fall prevention in older adults [49]. Our study found significant correlations between agility and physical activity levels, supporting evidence from Giné-Garriga et al., who observed marked improvements in dynamic balance following structured exercise interventions [50]. Such improvements are attributed to neuromuscular adaptations and enhanced proprioceptive control, which could serve as a critical focus for future interventions aimed at reducing fall risks in this demographic [51].

Lean body mass (LBM) was inversely correlated with lower body flexibility in our cohort. While this may initially seem contradictory, it highlights the complexity of the relationship between muscle mass and joint range of motion. This finding aligns with suggestions from Distefano et al. that flexibility-focused interventions can complement strength training to balance muscle mass benefits with mobility improvements [52].

Overall, our study highlights the multifaceted nature of physical fitness in the elderly and underscores the need for comprehensive interventions that address strength, flexibility, cardiovascular health, and body composition. Future studies should consider integrating high-intensity, multi-component exercise regimens to optimize physical and functional outcomes in older adults. The evidence underscores the necessity of tailored exercise programs to improve the quality of life and physical independence in aging populations, drawing from successful interventions documented in similar research [53].

The observations and comparisons provided valuable insights into the effectiveness of different exercise modalities in improving physical fitness and addressing body composition challenges in older adults. Collectively, these findings reinforce the critical role of physical activity in reducing age-related decline in physical health and function. Our results demonstrate that body composition plays an important role in physical fitness outcomes. Addressing these factors in fitness programs can improve the quality of life and health in elderly populations.

Conclusion

In conclusion, this study demonstrates that body composition, particularly body fat percentage and BMI, has a significant negative impact on physical fitness outcomes such as strength, flexibility, and cardiovascular health in older adults. Specifically, reduced flexibility and cardiovascular fitness were observed in individuals with higher BMI. Targeted stretching and exercise interventions, such as high-intensity exercise programs, can improve strength, balance, and reduce fall risk in the elderly. These findings highlight the importance of developing tailored, comprehensive exercise programs to enhance physical fitness and quality of life in older adults, particularly for those with elevated BMI and body fat percentage. Addressing these factors in fitness programs may help optimize physical health and functional independence in elderly populations.

Ethical Considerations:

Compliance with ethical guidelines

The authors commit to adhering to ethical guidelines.

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Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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«مقاله پژوهشی»

استفاده از آنالیز امپدانس بیوالکتریکی و دستگاه های تناسب اندام هوشمند در ارزیابی آمادگی جسمانی و ترکیب بدن در میان سالمندان

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چکیده

هدف: جمعیت جهان افزایش قابل توجه و قابل توجهی را در تعداد و نسبت افراد مسن تجربه می کند که چالش های منحصر به فردی را ارائه می دهند. هدف این مطالعه ارزیابی سطوح آمادگی جسمانی در میان سالمندان با استفاده از ابزارهای ارزیابی معتبر برای حمایت از برنامه ریزی مبتنی بر شواهد و توسعه مداخلات هدفمند در سلامت سالمندان است.

روش شناسی: این مطالعه مقطعی شامل ۲۱۰ سالمند ۶۰ سال به بالا بود که به روش نمونه گیری تصادفی خوشه ای انتخاب شدند. داده‌ها با استفاده از ترکیبی از معیارهای عینی و گزارش‌شده، از جمله دستگاه‌های تناسب اندام هوشمند (ردیاب تناسب اندام موبایل) برای نظارت بر فعالیت در زمان واقعی جمع‌آوری شدند. ارزیابی‌های آنتروپومتریک و آنالیز امپدانس بیوالکتریکی (BIA) برای ارزیابی ترکیب بدن استفاده شد. پرسشنامه بین المللی فعالیت بدنی (IPAQ) و آزمون تناسب اندام سالمندان (SFT) سطوح فعالیت بدنی و آمادگی عملکردی را با داده های اضافی جمع آوری شده از مصاحبه های ساختاریافته ارزیابی کرد. تایید اخلاقی و رضایت آگاهانه اخذ شد. تجزیه و تحلیل داده ها با استفاده از نرم افزار SPSS نسخه ۲۷ و با آمار توصیفی و ضریب همبستگی پیرسون برای بررسی رابطه بین آمادگی جسمانی و ترکیب بدن انجام شد.

نتایج: بین درصد چربی بدن و پارامترهای مختلف آمادگی جسمانی همبستگی منفی و معناداری مشاهده شد. به طور خاص، درصد چربی بدن با قدرت پایین بدن (r= −۰/۲۵، p<۰/۰۰۱)، قدرت بالاتنه (r= −۰/۲۲ ، p<۰/۰۰۱)، و انعطاف پذیری پایین بدن (r= −۰/۲۲ ، p<۰/۰۰۱) همبستگی منفی داشت. این نتایج نشان می دهد که افزایش چربی بدن با کاهش قدرت و انعطاف پذیری در افراد مسن مرتبط است.

نتیجه گیری: یافته‌های ما نشان می‌دهد که ترکیب بدن، به‌ویژه افزایش درصد چربی بدن و BMI، تأثیر منفی بر قابلیت‌های فیزیکی مانند قدرت، انعطاف‌پذیری و سلامت قلبی عروقی در افراد مسن دارد. کاهش مشاهده شده در انعطاف پذیری و ظرفیت قلبی عروقی بر ضرورت مداخلات هدفمند، از جمله برنامه های تمرینی کششی و ساختارمند با شدت بالا، برای بهبود قدرت، تعادل و کاهش خطرات سقوط تاکید می کند. استراتژی های ورزشی مناسب برای تقویت ترکیب بدن، بهینه سازی آمادگی جسمانی و بهبود سلامت کلی و کیفیت زندگی در سالمندان ضروری است.

واژه‌های کلیدی: آمادگی جسمانی، انعطاف پذیری، ترکیب بدن، جمعیت سالمند، سلامت قلب و عروق، قدرت عضلانی.