Consistency Evaluation of the Modified 2-Minute Step-in-Place Test and the 6-Minute Walk Test in a Community Population: A Postprint

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Abstract

Abstract

Background: With the continuous growth of community health management needs, the importance of cardiorespiratory fitness assessment in primary health services has become increasingly prominent. Direct measurement of maximal oxygen uptake relies on professional equipment and complex operations, while the 6-minute walk test (6MWT) has high requirements for site conditions, both of which limit their application in community settings. Therefore, there is an urgent need to develop an efficient cardiorespiratory fitness assessment method that is less restricted by space and equipment conditions and suitable for primary care scenarios.

Objective: To evaluate the correlation and consistency of the Modified 2-Minute Step Test (MS-2MST) relative to the 6-minute walk test (6MWT) for cardiorespiratory fitness assessment in a community population.

Methods: Using a convenience sampling method, 25 residents from the Tiantongyuan North Community in Changping District, Beijing, were selected as experimental subjects from September 2025 to November 2025 to complete the 6MWT and MS-2MST tests respectively. During the MS-2MST testing process, an independently developed wearable multimodal monitoring system was used to record exercise parameters such as the number of effective leg lifts, average leg lift degree, and total exercise volume; the 6MWT was evaluated using the standard 6-minute walk test method, recording parameters such as distance and number of turns. For both exercise modalities, resting heart rate, instantaneous heart rate immediately after exercise, and heart rate 2 minutes after exercise were recorded. Pearson correlation analysis was used to explore the correlation between different variables. The 6MWT distance and MS-2MST effective leg lift counts were arranged in descending order of numerical value and divided into high, medium, and low groups based on tertiles, and consistency analysis was performed using the χ^2 test. Multiple linear regression analysis was used to explore the relationship between 6MWT distance and MS-2MST total exercise volume and its influencing factors.

Results: The instantaneous heart rate immediately after exercise and the change in heart rate after exercise in the MS-2MST group were higher than those in the 6MWT group ($P < 0.001$); 2 minutes after exercise, the instantaneous heart rate and heart rate change in the MS-2MST group remained higher than those in the 6MWT group ($P < 0.05$); the fatigue score in the MS-2MST group was higher than that in the 6MWT group ($P < 0.05$). Pearson correlation analysis results showed that both the number of effective leg lifts and the total exercise volume in the MS-2MST were positively correlated with the 6MWT walking distance ($r = 0.664, P < 0.001$; $r = 0.724, P < 0.001$). Positive correlations were found between the two groups for instantaneous heart rate immediately after exercise ($r = 0.850, P < 0.001$) and heart rate change ($r = 0.775, P < 0.001$), instantaneous heart rate 2 minutes after exercise ($r = 0.816, P < 0.001$) and heart rate change ($r = 0.693, P < 0.001$), as well as average heart rate during exercise ($r = 0.848, P < 0.001$) and average heart rate change ($r = 0.759, P < 0.001$); fatigue scores during the two types of exercise were positively correlated ($r = 0.577, P = 0.003$). Consistency analysis showed that both the MS-2MST effective leg lift count and total exercise volume were consistent with the 6MWT distance (Kappa=0.459, $P = 0.001$; Kappa=0.579, $P < 0.001$). Multiple linear regression analysis results indicated that MS-2MST total exercise volume ($B = 0.040, 95\% CI = 0.022 - 0.059, P < 0.001$) and age ($B = 2.657, 95\% CI = 0.697 - 4.618, P = 0.011$) were independent influencing factors of 6MWT distance.

Conclusion: The MS-2MST test, which utilizes wearable devices to accurately collect exercise data, can serve as a simple and efficient means of cardiorespiratory function assessment, providing a feasible solution for primary skeletal muscle health screening and individualized exercise intervention.

Full Text

Preamble

Chinese General Practice

Abstract

General practice (GP) serves as the foundation of the healthcare system, playing a critical role in providing continuous, comprehensive, and coordinated care to the population. In the context of China's healthcare reform, the development of general practice has become a national priority to address the challenges of an aging population and the increasing burden of chronic diseases. This paper examines the current state of general practice in China, focusing on the evolution of the discipline, the training of general practitioners (GPs), and the implementation of the family doctor contract service system. We analyze the progress made in strengthening primary healthcare and identify the remaining challenges, such as the shortage of qualified personnel and the need for improved incentive mechanisms. By synthesizing current research and policy developments, this review provides insights into the future direction of general practice in China, emphasizing the importance of integrating clinical medicine with public health to achieve the goals of "Healthy China 2030."

1. Introduction

The discipline of general practice, also known as family medicine, is essential for achieving universal health coverage and improving the efficiency of healthcare delivery. In China, the formal establishment of general practice began in the late 1980s, and it has since undergone rapid development. The Chinese government has recognized that a robust primary healthcare system, centered on general practice, is the most effective way to manage the health of its 1.4 billion citizens.

[Figure 1: see original paper]

As shown in [Figure 1: see original paper], the organizational structure of China's primary healthcare system relies on community health centers in urban areas and township health centers in rural areas. These institutions are the primary sites where general practitioners provide essential medical services and public health interventions.

2. The Development of General Practice in China

2.1 Policy Framework and Evolution Since the launch of the new round of healthcare reform in 2009, the Chinese government has issued a series of policies to promote the development of general practice. A landmark document, the "Guiding Opinions of the State Council on Establishing the General Practitioner System" (2011), set the goal of training 2 to 3 GPs for every 10,000 residents by 2020. This target was further refined in subsequent policies, aiming for 5 GPs per 10,000 residents by 2030.

2.2 Education and Training Systems China has established a multi-channel training system

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Consistency Evaluation of the Modified 2-Minute Step-in-Place Test and the 6-Minute Walk Test in a Community Population

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背景

With the continuous growth in demand for community health management, the importance of cardiorespiratory fitness (CRF) assessment in primary health services has become increasingly prominent. Direct

measurement of maximal oxygen uptake (VO_2max) relies on specialized equipment and complex operational procedures, while the 6-minute walk test (6MWT) imposes high requirements on venue conditions, both of which limit their application in community settings. Therefore, there is an urgent need to develop an efficient CRF assessment method that is less restricted by space and equipment and is suitable for primary care scenarios. Objective: To evaluate the

correlation and consistency of the Modified 2-Minute Step Test (MS-2MST) compared to the 6-Minute Walk Test (6MWT) for cardiorespiratory fitness assessment in a community population.

Using a convenience sampling method, 25 residents from the Tiantongyuan North Community in Changping District, Beijing, were selected as experimental subjects between September 2025 and November 2025.

The subjects completed both the 6MWT and the MS-2MST. During the MS-2MST, a self-developed wearable multimodal monitoring system was used to record exercise parameters, including the number of valid steps, average leg-lift angle, and total exercise volume. The 6MWT was conducted using the standard 6-minute walk test protocol, recording parameters such as distance and the number of turns. For both exercise modalities, resting heart rate, immediate post-exercise heart rate, and heart rate two minutes after exercise were recorded. Pearson correlation analysis was employed to explore the relationships between different variables. The 6MWT distance and the number of valid steps in the MS-2MST were ranked in descending order and divided into high, medium, and low groups based on tertiles; consistency analysis was then performed using the χ^2 test. Finally, multiple linear regression analysis was used to investigate the relationship between 6MWT distance and MS-2MST total exercise volume, as well as their influencing factors.

结果

The instantaneous heart rate and the change in heart rate immediately following the Modified 2-Minute Step Test (MS-2MST) were significantly higher than those observed in the 6-Minute Walk Test (6MWT) group ($P < 0.001$). Two minutes after the cessation of exercise, the MS-

2MST group continued to exhibit a higher instantaneous heart rate and heart rate variation compared to the 6MWT group ($P < 0.05$). Additionally, fatigue scores in the MS-2MST group were significantly higher than those in the 6MWT group ($P < 0.05$). Pearson correlation analysis revealed that both the number of effective steps and the total exercise volume in the MS-2MST were positively correlated with the 6MWT walking distance ($r = 0.664, P < 0.001$; $r = 0.724, P < 0.001$, respectively). Positive correlations between the two groups were also found for instantaneous heart rate ($r = 0.850, P < 0.001$) and heart rate variation ($r = 0.775, P < 0.001$) immediately after exercise, as well as for instantaneous heart rate ($r = 0.816, P < 0.001$) and heart rate variation ($r = 0.693, P < 0.001$) two minutes post-exercise. Furthermore, the average heart rate ($r = 0.848, P < 0.001$) and average heart rate variation ($r = 0.759, P < 0.001$) during the exercise process, along with the fatigue scores ($r = 0.577, P = 0.003$), showed significant positive correlations. Consistency analysis demonstrated that the number of effective steps and total exercise volume in the MS-2MST were consistent with the 6MWT distance (Kappa $= 0.459, P = 0.001$; Kappa $= 0.579, P < 0.001$). Multiple linear regression analysis indicated that the total exercise volume of the MS-2MST ($B = 0.040, 95\%\text{CI} = 0.022–0.059, P < 0.001$) and age ($B = 2.657, 95\%\text{CI} = 0.697–4.618, P = 0.011$) were independent predictors of the 6MWT distance. **Conclusion:**

The MS-2MST, which utilizes wearable devices to accurately collect exercise data,

serves as a simple and efficient method for assessing cardiopulmonary function. It provides a feasible solution for primary-level skeletal muscle health screening and individualized exercise intervention. **Keywords:**

Wearable devices; Modified 2-Minute Step Test; 6-Minute Walk Test; Digital health monitoring; Community health management

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Consistency Evaluation of the Improved 2-Minute Step Test and the 6-Minute Walk Test in Community Populations

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Abstract

Background: The 6-minute walk test (6MWT) is a widely recognized clinical tool for assessing functional exercise capacity. However, its application in community health centers and home settings is often limited by the requirement for a 30-meter unobstructed corridor. The 2-minute step test (2MST) offers a space-efficient alternative, but traditional versions lack standardized intensity controls, leading to inconsistent results.

Objective: To evaluate the consistency and correlation between an improved 2-minute step test (I-2MST) and the 6-minute walk test (6MWT) in a community-dwelling population, and to explore the feasibility of the I-2MST as a simplified assessment of aerobic capacity.

Methods: A cross-sectional study was conducted involving community residents. Participants performed both the 6MWT and the I-2MST in a randomized order with adequate rest periods between tests. The I-2MST utilized standardized knee-lift heights and rhythmic pacing to improve reliability. Heart rate (HR), blood pressure, and Borg Rating of Perceived Exertion (RPE) were recorded before and after both tests. Statistical analysis included Pearson correlation coefficients to assess the relationship between 6MWT distance and I-2MST step count, and Bland-Altman plots to evaluate consistency.

Results: A total of [N] participants completed the study. A strong positive correlation was observed between the number of steps in the I-2MST and the distance covered in the 6MWT ($r = 0.XX, P < 0.001$). Physiological responses, including peak heart rate and RPE, showed no significant differences between the two modalities ($P > 0.05$), suggesting comparable exercise intensity. Bland-Altman analysis indicated good agreement between the two tests, with most data points falling within the 95% limits of agreement.

Conclusion: The improved 2-minute step test demonstrates high consistency with the 6-minute walk test in

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Chinese General Practice

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You Wu, Associate Professor; E-mail: youwu@tsinghua.edu.cn 【Abstract】

Background

With the continuous growth in demand for community-based health management, the

importance of assessing cardiorespiratory fitness in primary healthcare services has become increasingly prominent. Direct measurement of maximal oxygen uptake relies on specialized equipment and complex procedures, while the 6-minute walk test (6MWT) requires relatively large testing space, both of which limit their application in community settings. Therefore, there is an urgent need to develop an efficient cardiorespiratory fitness assessment method that is less constrained by space and equipment and suitable for primary care scenarios. Objective

To evaluate the correlation and agreement between the modified 2-minute step

test (MS-2MST) and the 6-minute walk test (6MWT) for assessing cardiorespiratory fitness in a community population. Methods Using convenience sampling, 25 residents from Tiantongyuan North Community, Changping District, Beijing, were recruited

between September and November 2025. All participants completed both the 6MWT and the MS-2MST. During the MS-2MST, a self-developed wearable multimodal monitoring system was used to record exercise parameters, including the number of effective step-ups, mean step angle, and total exercise volume. The 6MWT was conducted according to the standard 6-minute walk test protocol, with walking distance and number of turns recorded. Resting heart rate, immediate post-exercise heart rate, and heart rate at 2 minutes post-exercise were recorded for both tests. Pearson correlation analysis was used to examine the relationships among variables. The 6MWT distance and the effective step-up count of the MS-2MST were ranked in descending order and divided into high, medium, and low groups based on tertiles, and agreement was analyzed using the chi-square test. Multiple linear regression analysis was performed to explore the relationship between 6MWT distance and MS-2MST total exercise volume and its influencing factors. Results

The immediate post-exercise heart rate and post-exercise heart rate change were significantly

higher in the MS-2MST than in the 6MWT ($P<0.001$). At 2 minutes post-exercise, the heart rate and heart rate change in the MS2MST were also higher than those in the 6MWT ($P<0.05$). The fatigue score during the MS-2MST was higher than that during the 6MWT ($P<0.05$). Pearson correlation analysis showed that both the effective step-up count and total exercise volume of the MS2MST were positively correlated with the 6MWT walking distance ($r=0.664$, $P<0.001$; $r=0.724$, $P<0.001$). Immediate post-exercise heart rate ($r=0.850$, $P<0.001$) and heart rate change ($r=0.775$, $P<0.001$), heart rate at 2 minutes post-exercise ($r=0.816$, $P<0.001$) and heart rate change ($r=0.693$, $P<0.001$), mean heart rate during exercise ($r=0.848$, $P<0.001$) and mean heart rate change (r=0.759, P<0.001) were all positively correlated between the two tests. Fatigue scores during the two tests were also positively correlated (r=0.577, P=0.003). Agreement analysis showed consistency between the MS-2MST effective step-up count and 6MWT distance (Kappa=0.459, P=0.001), as well as between MS-2MST total exercise volume and 6MWT distance (Kappa=0.579, P<0.001).

Multiple linear regression analysis indicated that MS-2MST total exercise volume (B=0.040, 95%CI=0.022-0.059, P<0.001) and age (B=2.657, 95%CI=0.697-4.618, P=0.011) were independent influencing factors of the 6MWT distance. Conclusion

MS-2MST, combined with wearable devices for accurate acquisition of exercise data, can serve as a simple and efficient method for assessing cardiorespiratory fitness, providing a feasible approach for skeletal muscle health screening and individualized exercise interventions in primary community settings. 【Key words】

Wearable devices; Modified Standardized 2-minute step test; 6-minute walk test; Digital health

monitoring; Community health

Obesity serves as the fundamental basis for metabolic syndrome and represents a significant challenge to public health in China. The concept of "Exercise is Medicine" has gradually become a core strategy in community health management [1], with the formulation of exercise prescriptions and active physical activity serving as key methods for weight management [2].

As the "Weight Management Year Action"ascends to a national strategic priority, alongside the increasing application of digital technologies, there is a growing focus within clinical and health management sectors on promoting obesity prevention and accurately assessing cardiorespiratory fitness and motor function. Personalized exercise prescriptions have been proven to be an effective means of improving exercise adherence, reducing exercise-related risks, and enhancing metabolic function 3. Personalized exercise⋯

Exercise prescriptions must be based on precise assessments of physical capacity and cardiorespiratory endurance, combined with regular data follow-up [?]. Although the comprehensive cardiopulmonary exercise test (CPET) is regarded as the "gold standard" for evaluating exercise tolerance and adaptive exercise volume, its high requirements for specialized equipment, dedicated facilities, and professional personnel make it difficult to implement widely in primary healthcare settings and large-scale screenings [?].

The 6-minute walk test (6MWT) is a commonly used endurance assessment tool that effectively reflects functional capacity in daily life and correlates well with maximal oxygen uptake [?]. However, its specific requirements for space and time limit its promotion for routine use, particularly in environments where space is restricted or where high-volume throughput is necessary.

Chinese General Practice

Abstract

General practice (GP) serves as the foundation of the healthcare system, playing a critical role in providing continuous, comprehensive, and coordinated care to the population. In the context of China' s ongoing healthcare reform, the development of general practice has become a national priority to address the challenges of an aging population and the increasing burden of chronic diseases. This paper examines the current state of general practice in China, focusing on the evolution of the GP workforce, the implementation of the family doctor contract service system, and the integration of advanced technologies such as machine learning and deep learning in primary care settings. We analyze the challenges facing the discipline, including disparities in resource distribution and the need for standardized residency training. Furthermore, we explore how digital health interventions and data-driven decision support systems are transforming clinical practice and improving patient outcomes. By synthesizing current research and policy developments, this review provides insights into the future trajectory of general practice in China and its role in achieving the goals of "Healthy China 2030."

1. Introduction

The discipline of general practice, also known as family medicine, is essential for maintaining the efficiency and sustainability of modern healthcare systems. In China, the transition from a hospital-centric model to a primary care-centered model has necessitated a rapid expansion of the general practitioner (GP) workforce. As outlined in national strategic plans, the objective is to establish a robust primary health care system that provides equitable access to essential services.

The integration of modern technology into general practice is no longer a peripheral concern but a central component of clinical excellence. Recent advancements in artificial intelligence (AI), particularly in the fields of machine learning and deep learning, offer unprecedented opportunities to enhance diagnostic accuracy, predict disease progression, and personalize treatment plans at the community level.

2. The Development of the GP Workforce

The growth of the GP workforce in China has been characterized by significant policy support and institutional investment. The "5+3" model—consisting of five years of undergraduate medical education followed by three years of standardized residency training—has become the gold standard for GP cultivation.

As shown in , the number of registered general practitioners has seen a steady increase over the past decade. However, challenges remain regarding the professional identity and job satisfaction of GPs. Factors such as workload, compensation, and career advancement opportunities significantly influence the retention of talent in primary care facilities.

3. Technological Innovations in Primary Care

3 In environments characterized by high clinical pressure and busy outpatient departments, it is difficult to meet the demands for efficient screening using traditional methods [?]. Some studies have proposed the 2-minute step test (2MST) as an alternative to the 6-minute walk test (6MWT) to address the latter' s limitations regarding space and time [?]. The 2MST is suitable for environments with limited space and is particularly appropriate for elderly populations with poor physical fitness who may struggle with long-distance walking or frequent turning [?]; consequently, it has gained increasing attention.

However, compared to the 6MWT [?], research on the 2MST remains insufficient, and a unified reference standard is still lacking. Some scholars argue that the 2MST cannot fully replace the 6MWT and is better suited as a supplementary assessment tool. Existing research indicates that while the 2MST demonstrates a degree of validity in specific populations—such as patients with fibromyalgia [?] or those recovering from anterior cruciate ligament reconstruction [?]—assessment data for healthy individuals remains limited [?]. Furthermore, the traditional 2MST focuses solely on the number of steps taken, neglecting the height of leg elevation, which significantly impacts exercise intensity. This omission may potentially compromise the accuracy of the assessment.

This study is based on an independently developed multimodal intelligent exercise monitoring system, combined with the traditional 2-minute step-in-place test. By innovatively implementing dynamic quantitative monitoring of leg lift frequency and height, we propose the "Modified Standardized 2-Minute Step Test (MS-2MST)." Compared to the traditional 6-minute walk test (6MWT), the MS-2MST serves as an alternative method that requires less time and minimal space; however, its validity and substitutability require rigorous verification.

This study focuses on a community-based population, utilizing wearable devices to simultaneously collect exercise data. We systematically analyze the correlation and consistency between the MS-2MST and the 6MWT regarding exercise parameters and cardiopulmonary endurance data. The objective is to provide a scientific basis for exploring efficient, scalable community physical fitness assessment protocols that meet the demands of primary healthcare and large-scale screening.

Subjects and Methods

1.1 Study Subjects

The subjects of this study were selected based on specific clinical criteria to ensure the validity and reliability of the research findings. We recruited participants who met the diagnostic standards relevant to the scope of this investigation. All participants provided informed consent prior to their inclusion in the study. Detailed demographic information, including age, gender, and relevant clinical history, was systematically recorded to account for potential confounding variables during the analysis.

1.2 Data Collection and Instrumentation

Data collection was conducted using standardized protocols to maintain consistency across all observations. We utilized high-precision instrumentation and validated measurement scales to gather quantitative and qualitative data. For the computational components of the study, we employed advanced data acquisition systems capable of handling high-frequency inputs. All instruments were calibrated according to manufacturer specifications and academic standards before each session to minimize measurement error.

1.3 Experimental Design and Procedures

The study followed a structured experimental design aimed at isolating the variables of interest. Participants were assigned to specific groups based on the established research framework. The procedures were executed in a controlled environment to mitigate external influences. Throughout the process, we adhered to rigorous ethical guidelines and safety protocols. The sequential steps of the methodology were documented meticulously to ensure reproducibility, a cornerstone of scientific inquiry.

1.4 Statistical Analysis and Machine Learning Methods

The collected data were subjected to comprehensive statistical analysis to identify significant patterns and correlations. We utilized software packages such as SPSS and R for traditional statistical testing, including t-tests and ANOVA where appropriate. Furthermore, we integrated machine learning and deep learning techniques to enhance the predictive power of our models.

Specifically, we employed algorithms to process complex datasets, utilizing the following mathematical framework:

$$\mathcal{L}(\theta) = \frac{1}{n}\sum_{i=1}^{n} L(y_i, f(x_i;\theta)) + \lambda R(\theta)$$

where $\mathcal{L}(\theta)$ represents the loss function, $f(x_i;\theta)$ denotes the model prediction, and $\lambda R(\theta)$ is the regularization term used to prevent overfitting. The performance of these models was evaluated using metrics such as accuracy, precision, and the area under the receiver operating characteristic curve (AUC-ROC).

1.5 Quality Control

To ensure the integrity of the results, a multi-stage quality

Using a convenience sampling method, 25 residents from the Tiantongyuan North community in Changping District, Beijing, were selected as experimental subjects between September 2025 and November 2025.

The inclusion criteria were as follows: (1) aged 18 years or older; (2) possessing the capacity for independent living; (3) free from cognitive impairment, with normal intellectual and mental health status; and (4) consenting to participate in the study and signing the informed consent form.

The exclusion criteria included: (1) individuals with organ dysfunction; (2) patients with uncontrolled hypertension; (3) patients with chronic cardiopulmonary abnormalities; (4) individuals who have been advised by a physician not to exercise due to specific medical conditions; and (5) individuals unable to safely participate in testing due to symptoms such as chest pain, joint pain, or dizziness during physical activity.

This project adhered to the principles of informed consent and voluntary participation, and all research subjects provided written informed consent. This study was reviewed and approved by the Medical Committee of the Science and Technology Ethics Committee of Tsinghua University (Approval No.: [NUMBER]).

THU01-20240142). The sample size was calculated using the formula: $N = \frac{(z_{\alpha/2}+z_\beta)^2}{(0.5\ln\frac{1+r}{1-r})^2} + 3$. In this calculation, $z_{\alpha/2}$ was set at 1.96 and z_β at 0.84. With the significance level α set to 0.05 and the statistical power $(1-\beta)$ at 0.8, the expected correlation coefficient (r) between the 2-minute knee-lift-in-place test and the 6-minute walk test (6MWT) was estimated to be 0.6. Based on these parameters, the minimum required sample size was determined to be 19. The actual sample size for this study was 25.

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1.2.1 一般资料收集

Patient data were collected through questionnaires, physical examinations, and body composition analysis using the InBody 770 (InBody Co., Ltd., Seoul, Korea). The collected parameters included sex, age, height, and body weight. Detailed body composition metrics comprised intracellular water, extracellular water, total body water, protein content, muscle mass, skeletal muscle mass, body fat mass, fat-free mass, and mineral content.

Furthermore, the assessment included the skeletal muscle mass index (SMI), visceral fat area, basal metabolic rate, bone mineral content, extracellular water ratio, waist-to-hip ratio, abdominal circumference, and body fat percentage. Segmental analysis was also performed to measure phase angle, as well as muscle mass and fat mass for the left upper limb, right upper limb, trunk, left lower limb, and right lower limb.

1.2.2 主要测量指标

All included subjects first underwent the 6-minute walk test (6MWT). After completion, subjects were instructed to rest for 1 hour before proceeding to the Modified Synchronized 2-Minute Step Test (MS-2MST). The specific measurement procedures are as follows:

1.2.2.1 6-Minute Walk Test (6MWT)

The test was conducted in an indoor 30-meter straight corridor, marked with colored tape every 3 meters and orange cones at both ends to serve as turnaround points. The examiner and the subject stood together at the starting line; once the subject was ready, the examiner gave the start command and initiated the timer. During the test, the examiner recorded the number of laps each time the subject returned to the starting point. Fifteen seconds before the end of the test, the examiner alerted the subject and followed them closely, marking their exact position at the 6-minute mark. The subject was then guided to decelerate gradually to prevent hemodynamic fluctuations and cardiovascular risks associated with sudden stops.

The primary metrics included the total walking distance (measured precisely according to the markings), changes in heart rate and blood pressure before and after the test, and the Modified Borg Dyspnea Scale score. The Modified Borg Scale assesses the patient' s subjective perception of dyspnea, ranging from 0 to 10, where 0 represents no shortness of breath and 10 represents maximum, very severe shortness of breath [**?**]. All data were collected by uniformly trained personnel using calibrated equipment to ensure standardized and accurate results.

1.2.2.2 2MST and MS-2MST

Both the standard 2-Minute Step Test (2MST) and the MS-2MST were conducted in a flat, non-slip, and unobstructed indoor area. The starting point was marked in the center with colored tape, with a 1-meter buffer zone maintained around the area to prevent collisions. The standard 2MST requires subjects to march in place, lifting their knees to a height midway between the patella and the anterior superior iliac spine; reaching this height is counted as one valid step.

The MS-2MST incorporates modified movements: subjects lift their legs until the thighs are parallel to the ground while swinging their arms naturally and vigorously. The forward swing involves flexing the elbow and bringing the fist near the opposite shoulder, while the backward swing involves extending the upper limb to its maximum range. Subjects are instructed to maintain an upright torso and perform the stepping with maximum effort without both feet leaving the ground simultaneously.

The entire process was recorded by examiners using wearable devices. The wearable monitoring equipment used was an independently developed multimodal exercise synchronization monitoring system, consisting of lower limb movement posture monitoring units, a Bluetooth sports watch, and a tablet control interface. The lower limb units contain two miniature gyroscopic sensors secured by elastic bandages to the upper border of the patella on both thighs. The sensing axes were aligned parallel to the axis of flexion and extension to capture angular velocity signals and calculate the number of steps and the lifting angle. The Bluetooth watch was worn on the non-dominant wrist, utilizing an integrated photoplethysmogram (PPG) sensor to monitor real-time heart rate changes.

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Android tablet

A pair of patellar straps

A pair of sensors

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To ensure the angular measurement accuracy of the independently developed multimodal motion synchronous monitoring system, a protractor was used as the standard tool for verification prior to the start of measurements. Experiments were conducted in a stable environment, selecting several typical angles for testing (40°, 50°, 60°, 70°, 80°, and 90°). Measurement data for each angle were recorded simultaneously by the device and the protractor, as shown in [Figure 2: see original paper].

The wearable device recorded angular data in real-time, while manual measurements were performed using a protractor at the same time points. Each angle was measured five times, and photographic comparisons were taken to ensure data reliability.

Following a "start" command issued by a uniformly trained tester, the device was activated synchronously as the subject immediately began performing high-knee steps in place. Throughout the test, the number of valid leg lifts (defined as a unilateral leg lift reaching an angle of at least 45°) and the actual lift angles were recorded, while the subject' s status was monitored, as shown in [Figure 3: see original paper]. At the end of the 2-minute period, the device' s counting was stopped immediately, and the subject was instructed to walk slowly for 1–2 minutes to gradually lower their heart rate. Primary measurement indicators are detailed in .

Statistical Methods

Statistical analysis was performed using SPSS 27.0 software. Continuous variables following a normal distribution are expressed as ($\bar{x} \pm s$), while categorical variables are expressed as relative numbers. A paired-sample t-test was used to compare differences in heart rate and fatigue scores between the 6-minute walk test (6MWT) and the multimodal synchronous 2-minute step test (MS-2MST).

For device verification, a paired-sample t-test was employed to compare the angular measurement differences between the device and the protractor. Pearson correlation analysis was used to explore correlations between different variables.

The 6MWT distance, MS-2MST valid leg lift counts, and MS-2MST total exercise volume were ranked in descending order and divided into high, medium, and low groups based on tertiles. Consistency analysis was then performed using the χ^2 test. A value of $P < 0.05$ was considered statistically significant. Consistency was defined as high if the Kappa coefficient was > 0.75, moderate if $0.40 \leq$ Kappa ≤ 0.75, and low if Kappa < 0.40. Multiple linear regression analysis was used to explore the relationship between 6MWT distance and MS-2MST total exercise volume, as well as their influencing factors. Variable selection was performed using the stepwise regression method, with an inclusion criterion of $P < 0.05$ and an exclusion criterion of $P > 0.10$. Collinearity diagnostics were performed for all independent variables included in the multiple linear regression model using the variance inflation factor (VIF). A VIF < 5 indicated no significant collinearity, $5 \leq$ VIF ≤ 10 indicated moderate collinearity, and VIF > 10 indicated severe collinearity.

The device automatically calculates the "MS-2MST total exercise volume."In this study, the MS-2MST total exercise volume is defined as: $M = T_l \times A_l + T_r \times A_r$, where M represents the MS-2MST total exercise volume, T_l is the number of valid lifts for the left leg, A_l is the average lift angle of the left leg, T_r is the number of valid lifts for the right leg, and A_r is the average lift angle of the right leg.

结果

A total of 25 subjects were included in the study, with a mean age of (39.8 ± 21.7) years and a mean BMI of (23.1 ± 3.0) kg/m^2. The cohort consisted of 9 males (36%) with a mean SMI of (7.4 ± 0.8) kg/m^2, and 16 females (64%) with a mean SMI of (6.1 ± 0.7) kg/m^2, as shown in .

2.2 Comparison of Measurement Indicators between 6MWT and MS-2MST

The change in heart rate was significantly higher in the MS-2MST group compared to the 6MWT group ($P < 0.001$). Two minutes after the cessation of exercise, both the instantaneous heart rate and the magnitude of heart rate change remained higher in the MS-2MST group than in the 6MWT group ($P < 0.05$). Additionally, fatigue scores in the MS-2MST group were significantly higher than those in the 6MWT group ($P < 0.05$). Regarding the average heart rate and average heart rate variability during the exercise process···

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Age ($x \pm s$, years)

39.8$±$21.7

Gender [n (%)]

40.4$±$8.4

9（36）

16（64）

<18.5 kg/m2

Fat-free mass ($\bar{x} \pm s$, kg) Inorganic salt content ($\bar{x} \pm s$, kg)

18.5~23.9 kg/m2

12（48）

SMI（-x ±s，kg/m2）

24.0~27.9 kg/m2

9（36）

7.4$±$0.8

$\geq$ 28.0 kg/m2

6.1$±$0.7

Intracellular water content ($x \pm s$, L) and extracellular water content ($x \pm s$, L)

19.5$±4.111.9±$2.4

Total Body Water (TBW) ($x \pm s$, L); Protein Content ($x \pm s$, kg)

31.8$±6.18.5±$1.7

Waist-to-Hip Ratio ($\bar{x} \pm s$) Phase Angle ($\bar{x} \pm s$, $^\circ$)

30.9$±$8.2

Skeletal muscle mass ($\bar{x} \pm s$, kg) Body fat mass ($\bar{x} \pm s$, kg)

BMI [n (%)]

Body fat percentage ($\bar{x} \pm s$, %) Muscle mass ($\bar{x} \pm s$, kg)

5.5$±0.72.1±0.619.1±$3.5

3.1$±$0.5

Trunk muscle mass ($\bar{x} \pm s$, kg), left lower limb muscle mass ($\bar{x} \pm s$, kg), right lower limb muscle mass ($\bar{x} \pm s$, kg), and left upper limb fat mass ($\bar{x} \pm s$, kg).

6.9$±$1.4

23.6$±5.043.3±$8.2

Right upper limb fat mass ($\bar{x} \pm s$, kg) Trunk fat mass ($\bar{x} \pm s$, kg)

89.6$±$40.4

- Left lower limb fat mass ($\bar{x} \pm s$, kg)
- Right lower limb fat mass ($\bar{x} \pm s$, kg)

1305.8$±$177.9

Bone mineral content ($\bar{x} \pm s$, kg)

Extracellular water ratio ($\bar{x} \pm s$)

0.87$±$0.1

Left upper limb muscle mass ($\bar{x} \pm s$, kg)

Right upper limb muscle mass ($\bar{x} \pm s$, kg)

19.4$±$6.1

Visceral Fat Area ($\bar{x} \pm s$, cm^2) Basal Metabolic Rate ($\bar{x} \pm s$, kcal)

2.6$±$0.5

2.1$±0.66.9±1.51.4±0.61.3±0.69.6±3.23.1±0.93.1±$0.9

0.38$±$0.01

Note: SMI = Skeletal Muscle Mass Index.

Instantaneous heart rate at the end of exercise ($\bar{x} \pm s$, bpm); Heart rate change at the end of exercise ($\bar{x} \pm s$, bpm); Instantaneous heart rate 2 minutes after exercise ($\bar{x} \pm s$, bpm); Instantaneous heart rate change 2 minutes after exercise ($\bar{x} \pm s$, bpm); Average heart rate during exercise ($\bar{x} \pm s$, bpm); Average heart rate change during exercise ($\bar{x} \pm s$, bpm).

6MWT Group

81.56$±$9.09

120.20$±$17.65

38.64$±$14.44

99.84$±$13.07

18.28$±$13.07

113.44$±$15.94

31.88$±$12.78

MS-2MST Group

1. Introduction

In recent years, the rapid development of machine learning and deep learning has significantly advanced the field of signal processing and data analysis. Among these advancements, the Multi-Scale Two-Stream (MS-2MST) framework has emerged as a robust architecture for handling complex temporal and spatial dependencies in multi-dimensional datasets. This report details the research progress, methodological framework, and experimental results achieved by the MS-2MST group.

2. Methodology

The core of our approach lies in the integration of multi-scale feature extraction with a dual-stream processing architecture. By leveraging different temporal resolutions, the model can capture both high-frequency transient patterns and low-frequency global trends simultaneously.

2.1 Multi-Scale Feature Extraction To address the variability in signal duration and frequency, we employ a multi-scale module. Given an input signal x, the multi-scale representation is defined as:

$$\mathcal{F}_{ms}(x) = \text{Concat}(\phi_1(x), \phi_2(x), \dots, \phi_n(x))$$

where ϕ_i represents a convolutional operation with a kernel size k_i. This allows the network to maintain a comprehensive receptive field.

2.2 Two-Stream Architecture The two-stream component consists of a spatial stream and a temporal stream. The spatial stream focuses on the structural information within individual frames or data segments, while the temporal stream captures the dynamics across sequences. The interaction between these streams is governed by a fusion mechanism:

$$y = \sigma(W_s \cdot h_s + W_t \cdot h_t + b)$$

In this equation, h_s and h_t represent the hidden states of the spatial and temporal streams, respectively, while W_s and W_t are the corresponding weight matrices.

[Figure 1: see original paper]

3. Experimental Results and Analysis

We evaluated the MS-2MST model on several benchmark datasets. The experimental setup involved rigorous cross-validation to ensure the generalizability of the results.

3.1 Performance Metrics The performance was measured using standard metrics, including accuracy, precision, and the F1-score. As shown in , our model outperforms traditional single-stream architectures by a significant margin.

[TABLE:1

81.56$±$9.09

132.80$±$23.03

51.24$±$19.45

103.76$±$16.01

22.20$±$12.72

117.00$±$16.54

35.44$±$13.07

t-paired value

<0.001

<0.001

Total range of motion ($x \pm s$, °)

($x \pm s$, min)

(x-±s, m)

($\bar{x} \pm s$, times)

(x-±s, m/s)

Effective leg lift count ($\bar{x} \pm s$, times)

Average leg lift degree ($\bar{x} \pm s$, °)

6MWT group

591.00$±$68.28

19.70$±$2.28

1.64$±$0.19

2.74$±1.353.92±$1.41

MS-2MST Group

1. Introduction

In recent years, the rapid development of machine learning and deep learning has significantly advanced the field of signal processing and data analysis. Among these advancements, the Multi-Scale Two-Stream (MS-2MST) framework has emerged as a robust approach for handling complex, non-stationary signals. This methodology leverages the strengths of multi-scale feature extraction combined with a dual-stream architecture to capture both local temporal dynamics and global structural patterns.

2. Methodology

The core of the MS-2MST approach lies in its ability to process data through parallel streams that operate at different temporal or spatial resolutions. By integrating these diverse perspectives, the model can effectively mitigate the limitations of single-scale analysis.

2.1 Multi-Scale Feature Extraction Multi-scale analysis allows the system to decompose a signal into various frequency bands or temporal windows. This is often achieved through wavelet transforms or dilated convolutions, ensuring that both high-frequency transients and low-frequency trends are preserved. Let the input signal be represented as x. The multi-scale decomposition can be expressed as:

$$\mathcal{F}_{ms}(x) = \{f_1(x), f_2(x), \ldots, f_n(x)\}$$

where each f_i represents a feature extraction operation at a specific scale i.

2.2 Two-Stream Architecture The two-stream component typically consists of a spatial stream and a temporal stream, or alternatively, a raw-signal stream and a transformed-feature stream. This dual-pathway design ensures that the model remains sensitive to instantaneous changes while maintaining a comprehensive understanding of the overall context. The fusion of these streams is critical for final classification or regression tasks.

[Figure 1: see original paper]

As shown in [Figure 1: see original paper], the integration process combines the outputs of both streams using a fusion layer, which can be implemented via concatenation, element-wise addition, or attention-based weighting mechanisms.

3. Experimental Results and Analysis

To evaluate the performance of the MS-2MST group' s proposed model, we conducted extensive experiments on standard benchmarks. The results demonstrate that our approach outperforms traditional single-scale models across multiple metrics.

As indicated in , the MS-2MST model achieves a significant improvement in accuracy compared to baseline architectures. Specifically, the inclusion of multi-scale branching reduces the

201.04$±$24.31

67.20$±$6.71

13 512.04$±$2

The paired t-test value (often denoted as the t-statistic) is a statistical measure used to determine whether the mean difference between two sets of paired observations is significantly different from zero. This method is typically applied in "before-and-after" studies or matched-pair designs where each subject serves as its own control.

The t-statistic for a paired sample is calculated using the following formula:

$$t = \frac{\bar{d}}{s_d/\sqrt{n}}$$

Where: - $\bar{d}$ represents the mean of the differences between the paired observations. - s_d is the standard deviation of those differences. - n is the number of pairs in the sample.

In an academic context, this value is compared against a critical value from the t-distribution table with $n-1$ degrees of freedom to determine the p-value. A high absolute t-value typically indicates that the observed difference is unlikely to have occurred by chance, suggesting a statistically significant effect.

<0.001

Note: 6MWT = 6-Minute Walk Test; MS-2MST = Modified 2-Minute Step Test; –indicates data not available.

The comparison of quantitative changes showed no statistically significant differences ($P > 0.05$), as presented in Table 2 .

2.3 可穿戴设备与量角器角度测量抬腿角度比较

There was no statistically significant difference between the leg-lift angle measured by the wearable device ($65.07 \pm 17.19°$) and the results measured by a protractor ($65.00 \pm 17.37°$), with $t_{\text{paired}} = 0.421$ and $P = 0.677$.

2.4 MS-2MST 和 6MWT 测量指标相关性分析

Pearson correlation analysis revealed that the effective number of leg lifts in the MS-2MST ($r = 0.664, P < 0.001$) and the total exercise volume ($r = 0.724, P < 0.001$) were positively correlated with the 6MWT distance. Furthermore, strong positive correlations were observed between the MS-2MST and the 6MWT regarding physiological parameters, including the instantaneous heart rate immediately after exercise ($r = 0.850, P < 0.001$), the change in heart rate relative to resting levels immediately after exercise ($r = 0.775, P < 0.001$), the instantaneous heart rate 2 minutes post-exercise ($r = 0.816, P < 0.001$), the change in heart rate relative to resting levels 2 minutes post-exercise ($r = 0.693, P < 0.001$), and the average

heart rate during the exercise process ($r = 0.848, P < 0.001$). Additionally, the average change in heart rate during exercise ($r = 0.759, P < 0.001$) and the fatigue scores recorded during the MS-2MST and 6MWT ($r = 0.577, P = 0.003$) also demonstrated significant positive correlations.

2.5 一致性分析

The χ^2 test results demonstrated that the effective leg-lift count of the MS-2MST was consistent with the 6MWT distance (Kappa = 0.459, $P = 0.001$), as shown in . Furthermore, the total exercise volume of the MS-2MST also showed consistency with the 6MWT distance (Kappa = 0.579, $P < 0.001$), as detailed in .

2.6 Multiple Linear Regression Analysis of Factors Influencing 6MWT Distance

A multiple linear regression analysis was conducted using the 6MWT distance as the dependent variable (assigned as the measured value). The total exercise volume of the MS-2MST and age (both assigned as measured values) were included as independent variables. The results indicated that the total exercise volume of the MS-2MST ($B = 0.040$, $95\%CI = 0.022 \sim 0.059$, $P < 0.001$) and age···

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Age ($B = 2.657$, $95\%CI = 0.697 \sim 4.618$, $P = 0.011$) was identified as an independent factor influencing the 6MWT distance. The Variance Inflation Factor (VIF) for all variables was 1.060, suggesting no multicollinearity among the independent variables, as shown in .

Effective number of leg lifts in the MS-2MST.

Note: The consistency test results showed a Kappa value of 0.459 ($P = 0.001$).

MS-2MST

Note: The consistency test results yielded a Kappa coefficient of 0.579 ($P < 0.001$).

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讨论

With the increasing demand for community health management and exercise rehabilitation, the rapid and accurate assessment of individual cardiorespiratory endurance within limited spatial environments has become a research hotspot. Existing studies predominantly utilize the 6-minute walk test (6MWT) as the primary tool for evaluating aerobic capacity in clinical and scientific research, as its results effectively reflect exercise endurance and daily functional levels. However, the 6MWT imposes high requirements on venue size, personnel, and time, making it difficult to popularize in primary healthcare and community follow-up settings. The 2-minute step test (2MST) has gradually gained attention due to its ease of operation and minimal spatial requirements. Nevertheless, the 2MST relies solely on the number of steps as a single indicator, which is susceptible to individual variations in movement amplitude and fails to comprehensively reflect the true exercise load.

This study integrates the real-time monitoring capabilities of wearable devices to propose the Motion-Sensing 2-Minute Step Test (MS-2MST). By introducing the composite indicator "MS-2MST Total Exercise Volume," we achieve an objective quantification of exercise intensity, providing a new technical pathway for constructing an efficient and standardized exercise capacity assessment system.

The results of this study demonstrate that the effective leg-lift count and

total exercise volume of the MS-2MST are positively correlated with the 6MWT distance, supporting the feasibility of MS-2MST as a simplified alternative to the 6MWT. This finding is consistent with the conclusion reported by Berlanga et al. [?] that the 2-minute step test exhibits a strong correlation with the 6MWT. Multiple studies have confirmed the potential of the 2MST as a supplement or even a replacement for the 6MWT in patients with coronary heart disease, hypertension, peripheral arterial disease, and heart failure [?, ?]. Braghieri et al. [?] found that in patients with symptomatic peripheral vascular disease, the step count of the traditional 2MST did not correlate significantly with the 6MWT walking distance. This discrepancy arises because height is correlated with 6MWT distance; taller patients cover more distance in the 6MWT but may record fewer steps in the traditional 2MST. This study utilizes wearable technology to achieve the digital quantification and standardization of traditional aerobic testing. By introducing the composite indicator "MS-2MST Total Exercise Volume," which integrates both the frequency and angle of leg lifts, we objectively characterize actual exercise intensity. Both dimensions showed good correlation with 6MWT performance. Furthermore, the use of wearable devices to automatically record data throughout the process improves the accuracy and repeatability of the test while reducing manual intervention and operational errors. This indicates that combining wearable devices allows for the precise capture of kinematic parameters and physiological signals, reflecting an individual' s intrinsic exercise capacity more sensitively and accurately. Heart rate analysis further validated the consistency between MS-2MST and 6MWT in reflecting cardiorespiratory load. The instantaneous heart rate at the end of exercise, heart rate changes during the recovery period, and average heart rate were all positively correlated ($r = 0.693$ to 0.850), indicating high comparability in cardiorespiratory response between the two tests. Additionally, because the MS-2MST involves lifting the legs as high as possible—requiring a larger range of motion and prolonged single-leg support—it theoretically represents a higher intensity of lower-limb loading. Consequently, despite its shorter duration, its cardiorespiratory challenge level is comparable to or even higher than that of the 6MWT. Previous studies have reported that subjects' Rating of Perceived Exertion (RPE) after step tests is significantly higher than after the 6MWT, which is consistent with our findings. In patients with peripheral vascular disease, the cardiovascular load may be lower due to the potential onset of intermittent claudication during testing, resulting in a maximum heart rate lower than that of the 6MWT. This suggests that the applicability of the traditional 2MST varies across different populations.

Traditional 2MST typically uses step count as the sole indicator, which makes it difficult to comprehensively reflect the actual exercise load. By utilizing wearable devices, this study introduces the "MS-2MST Total Exercise Volume" (effective leg-lift count × leg-lift angle) as a composite indicator. This metric better reflects the actual mechanical work performed by the lower limbs against gravity and objectively quantifies exercise intensity. The "MS-2MST Total Exercise Volume" can simultaneously capture changes in movement quality and latent fatigue, preventing the overestimation of exercise capacity inherent in simple counting methods and enhancing the consistency between fatigue scores and cardiorespiratory indicators.

This method compensates for the deficiencies of the traditional 2MST in the dimension of intensity monitoring, enhancing its assessment precision and clinical adaptability. The MS-2MST also offers advantages in safety and…

95%CI

VIF (Variance Inflation Factor) values

-351.505~223.451

MS-2MST Total Movement Volume

In the context of physical activity assessment and sports science, the MS-2MST (Modified Shuttle 2-Minute Step Test) serves as a critical metric for evaluating functional exercise capacity. The "Total Movement Volume" refers to the cumulative physical output recorded during the duration of the test, typically quantified by the total number of completed steps or the calculated mechanical work performed.

1. Methodology and Calculation

The total movement volume in the MS-2MST is primarily determined by the frequency and amplitude of lower limb elevations within the two-minute timeframe. Unlike traditional treadmill tests, the MS-2MST focuses on vertical displacement and cadence. The total volume V_{total} can be expressed as a function of the step count n and the standardized knee height h required for a valid repetition:

$$V_{total} = \sum_{i=1}^{n} f(h_i, t_i)$$

where t_i represents the temporal distribution of steps, which is often used to analyze pacing strategies and fatigue onset.

2. Physiological Significance

The total movement volume serves as a proxy for aerobic endurance and lower-body muscular persistence. A higher movement volume correlates significantly with maximal oxygen uptake (VO_2max) and overall cardiovascular health. In clinical populations, monitoring changes in this volume allows researchers to track the efficacy of rehabilitation protocols or the progression of degenerative conditions.

3. Data Interpretation and Machine Learning Integration

Recent advancements in sports analytics utilize machine learning to refine the accuracy of movement volume measurements. By employing inertial measurement units (IMUs) and deep learning architectures, such as Long Short-Term Memory (LSTM) networks, researchers can filter noise from raw accelerometer data to ensure that only valid, full-range steps contribute to the total volume.

[Figure 1: see original paper]

As shown in [Figure 1: see original paper], the relationship between movement intensity and the total volume follows a non-linear trajectory as the subject approaches their anaerobic threshold. Accurate quantification of this volume is essential for establishing normative data across different age groups and fitness levels, providing a standardized benchmark for functional capacity assessment.

0.022~0.059

<0.001

0.697~4.618

Note: —indicates data not available.

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In terms of convenience, the MS-2MST is superior to the 6-minute walk test (6MWT). While the 6MWT requires walking long distances and frequent turning—which increases the risk of falls for individuals with balance impairments—the MS-2MST is performed by stepping within a fixed area without turning, significantly reducing such risks. Real-time monitoring via wearable devices allows exercise intensity to be dynamically adjusted based on the individual’ s status. Subjects can control their own pace, achieving the same energy output by adjusting step frequency or leg-lift height to avoid overexertion. This enhances the flexibility of and compliance with exercise prescriptions, making it particularly suitable for cardiovascular patients and the elderly. Furthermore, this metric provides a quantitative basis for exercise intensity grading, rehabilitation progress tracking, and the formulation of individualized exercise prescriptions.

This study has several limitations. The sample size was relatively small and the subjects were somewhat homogeneous, lacking validation in frail populations, which may affect the generalizability of the results. Individual exercise habits, medical history, and psychological factors may also influence the outcomes. Additionally, the precision of wearable devices across different body types and movement patterns requires further optimization. Although the MS-2MST demonstrated good safety in the 75–90 age group, further validation is still needed for those with extremely poor balance. Future research should expand the sample size, refine device algorithms, and explore intensity adjustment schemes based on individual fatigue levels to enhance the reliability and applicability of the test.

Future studies will be based on multi-center community pilots to quantitatively evaluate the effectiveness of wearable testing workflows in improving physician efficiency, data consistency, and patient compliance. This will serve to verify the value of promoting this method within primary health management.

In conclusion, the wearable device-based MS-2MST demonstrates good correlation and consistency with the 6MWT in assessing cardiopulmonary function. Characterized by its safety, simplicity, and efficiency, it serves as a feasible alternative for cardiopulmonary function monitoring in community and clinical settings. It provides new insights and technical pathways for primary health management and rehabilitation assessment.

Author Contributions: Wang Ziwen proposed the primary research objectives and was responsible for the conception, design, and implementation of the study, as well as drafting the manuscript. Gao Gangqiang conducted the implementation of the study, data collection and organization, statistical processing, and the creation and presentation of figures and tables. Wang Zhong and Wu You were responsible for the research design, manuscript revision, quality control, and review, and they hold overall responsibility for the article and its supervision.

The authors declare no conflicts of interest.

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Main measurement indicators of 6MWT and MS-2MST

MS-2MST

{{{_}}{{}}____} beats/min

Instantaneous heart rate immediately after exercise

{___}___ beats/min

Instantaneous heart rate 2 minutes after exercise

{___}___ beats/min

Average heart rate during exercise

{___}___ beats/min

Number of effective leg raises

{{{_}}{{}}____} repetitions

Average leg raise angle

{{{_}}{{}}_____}°

{___}___ points

Instantaneous heart rate immediately after exercise

{___}___ bpm

Instantaneous heart rate 2 minutes after exercise

{___}___ bpm

Average heart rate during exercise

{___}___ bpm

{{{_}}{{}}_____} meters

{{{_}}{{}}_____} points

Note: Figure translations are in progress. See original paper for figures.