RESEARCH PAPER

Relationships Between Habitual Daily Step Count, Rectus Femoris Mechanical Properties, and Dynamic Balance in Healthy Young Women

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Abstract

Background: Habitual physical activity is known to contribute to musculoskeletal health and functional performance. Daily step count, which can be easily monitored using smartphones, has emerged as a practical indicator of free-living physical activity. However, limited evidence exists regarding the relationships among habitual daily step count, muscle mechanical properties, and dynamic balance in healthy young women.

Objective: This pilot study aimed to investigate the associations among seven-day average daily step count, rectus femoris muscle stiffness, and dynamic balance performance in healthy young women.

Methods: Five healthy female university students participated in this cross-sectional pilot study. Habitual physical activity was quantified using the average daily step count recorded by smartphone health applications over seven consecutive days. Rectus femoris muscle stiffness was assessed using a MyotonPRO device, while dynamic balance was evaluated using the anterior reach component of the Y-Balance Test (YBT). Spearman's rank correlation analysis was performed to examine the relationships among the study variables.

Results: A significant positive correlation was observed between average daily step count and normalized anterior YBT performance ($\rho = 1.000$, $p < 0.001$), indicating that participants with higher habitual physical activity demonstrated superior dynamic balance. In contrast, no significant correlations were found between daily step count and rectus femoris muscle stiffness ($\rho = -0.154$, $p = 0.805$) or between muscle stiffness and dynamic balance performance ($\rho = -0.154$, $p = 0.805$).

Conclusions: Habitual daily step count was positively associated with dynamic balance performance but not with rectus femoris muscle stiffness in healthy young women. These findings suggest that smartphone-derived step count may serve as a simple and accessible digital indicator of functional balance capacity. Given the exploratory nature of this pilot study and its limited sample size, further large-scale investigations are required to confirm these findings and clarify the mechanisms linking habitual physical activity, muscle mechanical properties, and functional performance.

Keywords: habitual physical activity; daily step count; muscle stiffness; rectus femoris; dynamic balance; Y-Balance Test; healthy young women

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I. Introduction

Physical inactivity has become one of the leading public health concerns worldwide owing to rapid technological advancement, increased reliance on motorized transportation, prolonged sedentary behavior, and the widespread adoption of smartphone-based lifestyles. Insufficient physical activity has been consistently associated with an increased risk of cardiovascular disease, metabolic disorders, obesity, premature mortality, and deterioration in musculoskeletal health and physical performance **[1–6]**. Recent epidemiological evidence indicates that a substantial proportion of adults fail to achieve the recommended level of physical activity, with particularly high prevalence among women **[4–6]**. Even among healthy young adults, reduced habitual physical activity may negatively influence neuromuscular function before clinically apparent musculoskeletal impairments develop **[2,5]**.

Among various indicators of habitual physical activity, daily step count has emerged as one of the most practical and objective measures for evaluating free-living physical activity. The widespread use of smartphones and wearable devices has enabled continuous monitoring of ambulatory activity, making daily step count an accessible digital biomarker of health behavior **[3,7,8]**. Numerous prospective studies and systematic reviews have demonstrated that higher daily step counts are associated with reduced all-cause mortality, improved cardiovascular health, enhanced quality of life, and superior physical function **[9–12]**. Consequently, average daily step count has become an increasingly valuable surrogate marker for assessing habitual physical activity in both clinical practice and population-based research **[8,9]**.

Beyond its influence on general health, habitual physical activity plays an essential role in maintaining skeletal muscle structure and function. Although muscle mass has traditionally been regarded as a major determinant of physical performance, increasing evidence suggests that muscle quality may provide a more sensitive indicator of functional capacity **[13,14]**. Muscle stiffness, representing one of the passive mechanical properties of skeletal muscle, reflects the viscoelastic characteristics of muscle tissue and is associated with force transmission efficiency, joint stability, and neuromuscular performance **[13,16]**. Regular physical activity may preserve or modify these mechanical properties through long-term neuromuscular adaptation **[13,16]**. Among the lower-extremity muscles, the rectus femoris plays a pivotal role in walking, stair negotiation, postural control, and other functional movements, making it a clinically relevant muscle for investigating the relationship between habitual physical activity and muscle mechanical properties **[17,18]**.

Dynamic balance is another fundamental component of physical function that depends on coordinated interactions among neuromuscular control, proprioceptive feedback, visual and vestibular inputs, and lower-extremity muscle performance **[19,20]**. The anterior reach component of the Y-Balance Test (YBT) has been widely used to evaluate dynamic postural control because it requires precise coordination of the hip, knee, and ankle joints while maintaining single-limb stability **[20,21,27]**. Previous studies have consistently demonstrated that physically active individuals exhibit superior balance performance compared with sedentary individuals, suggesting that habitual physical activity contributes to enhanced neuromuscular efficiency and postural stability **[22,29,31]**. Because impaired dynamic balance is associated with an increased risk of lower-extremity injury and functional decline, identifying modifiable factors that influence balance performance has important clinical implications **[19,21]**.

Despite accumulating evidence regarding the independent relationships between physical activity, muscle function, and balance performance, relatively few studies have simultaneously examined the associations among habitual daily step count, muscle mechanical properties, and dynamic balance in healthy young women. Furthermore, previous investigations have predominantly focused on older adults, athletes, or clinical populations, whereas evidence involving healthy young adults remains limited **[16,22,29,31]**. In particular, studies utilizing smartphone-derived daily step counts as an objective indicator of habitual physical activity to investigate their relationship with rectus femoris stiffness and functional balance are scarce **[23,24]**.

Therefore, the present pilot study aimed to investigate the associations among seven-day average daily step count, rectus femoris stiffness, and dynamic balance performance in healthy young women. We hypothesized that greater habitual physical activity, represented by higher average daily step counts, would be associated with superior dynamic balance performance and more favorable muscle mechanical characteristics. The findings of this study may provide preliminary evidence regarding the influence of habitual ambulatory activity on neuromuscular function and contribute to the development of evidence-based strategies for promoting musculoskeletal health and preventing functional decline in young adults.

II. Materials and Methods

2.1. Study Design and Participants

This pilot cross-sectional study investigated the associations among habitual physical activity, rectus femoris muscle stiffness, and dynamic balance performance in healthy young women. Five healthy female university students aged between 20 and 25 years voluntarily participated in the study.

Participants were eligible if they (1) were aged 20 years or older, (2) regularly used a smartphone equipped with a built-in health application capable of recording daily step counts (Samsung Health or Apple Health), and (3) had no history of lower-extremity musculoskeletal injury, neurological disorder, chronic pain, or balance impairment. Individuals with a history of lower-extremity surgery, spinal disorders, or any medical condition that could influence gait or postural control were excluded.

Before participation, all subjects received a detailed explanation of the study procedures and voluntarily provided written informed consent. Height was measured using an automatic anthropometric system (BSM 370, Biospace, Seoul, Korea), while body weight and lower-extremity skeletal muscle mass were assessed using a multifrequency bioelectrical impedance analyzer (InBody 970, Biospace, Seoul, Korea). Dominant leg was determined by asking participants which leg they naturally used to kick a ball.

2.2. Assessment of Habitual Physical Activity

Habitual physical activity was quantified using the participants' average daily step count over the previous seven consecutive days. Step-count data were obtained directly from the native smartphone health applications (Samsung Health or Apple Health), which continuously record ambulatory activity through built-in accelerometers.

The seven-day average step count (steps/day) was calculated from the recorded daily values and used as an objective indicator of habitual physical activity. Smartphone-based step counting has demonstrated acceptable validity and reliability compared with research-grade pedometers and accelerometers, supporting its application in free-living physical activity assessment [23,24].

2.3. Measurement of Rectus Femoris Muscle Stiffness

Mechanical properties of the rectus femoris were evaluated using a handheld digital myotonometer (MyotonPRO, Myoton AS, Tallinn, Estonia). Muscle stiffness was measured at the midpoint between the anterior superior iliac spine (ASIS) and the superior border of the patella, following standardized anatomical landmarks described in previous studies [25,26].

Participants rested comfortably in the supine position with both lower limbs fully relaxed to minimize involuntary muscle activation. The measurement probe was positioned perpendicular to the skin surface, and the device delivered a brief mechanical impulse to the underlying muscle tissue. Five consecutive measurements were automatically obtained, and the mean stiffness value (N/m) was used for statistical analysis. All assessments were performed by the same experienced examiner to minimize inter-rater variability.

2.4. Assessment of Dynamic Balance

Dynamic balance was evaluated using the anterior reach direction of the Y-Balance Test (YBT), a reliable and widely accepted assessment of lower-extremity postural control and functional balance [27,28].

Participants stood barefoot on the dominant leg while reaching as far as possible in the anterior direction with the contralateral limb without compromising balance. Before formal testing, participants completed several practice trials to familiarize themselves with the testing procedure. Three successful trials were subsequently recorded, and the mean reach distance was calculated.

To account for anthropometric differences among participants, reach distance was normalized to leg length using the following equation:

Normalized reach distance (%) = (Reach distance / Leg length) × 100

A trial was considered invalid if the participant removed the hands from the hips, failed to return to the starting position under control, touched the floor with the reaching foot for weight support, lifted or displaced the stance foot, or kicked the reach indicator to artificially increase the reach distance. Invalid trials were discarded and repeated until three successful trials were obtained.

2.5. Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were calculated for all demographic and outcome variables and are presented as mean ± standard deviation (SD) for continuous variables and frequency (percentage) for categorical variables.

Because of the small sample size (n = 5), assumptions of normality could not be adequately verified. Therefore, nonparametric statistical methods were employed. The relationships among seven-day average step count, rectus femoris muscle stiffness, and normalized anterior Y-Balance Test performance were examined using Spearman's rank correlation coefficient (ρ).

The strength of the correlations was interpreted according to established guidelines: negligible (<0.30), low (0.30–0.49), moderate (0.50–0.69), high (0.70–0.89), and very high (≥0.90). Statistical significance was determined using two-tailed tests with an alpha level of **p < 0.05**.

III. Results

3.1. Participant Characteristics

A total of five healthy young women participated in this pilot study. The mean age of the participants was **22.60 ± 1.34 years**, with a mean height of **164.60 ± 4.34 cm** and a mean body weight of **54.08 ± 2.26 kg**. All participants were right-leg dominant (100%), and the mean skeletal muscle mass of the dominant lower extremity was **5.54 ± 0.36 kg**. The demographic characteristics of the participants are presented in **Table 1**.

Table 1. General characteristics of the participants

	Mean ± SD or n (%)	p-value
Sex (female)	5 (100%)	-
Age (years)	22.60 ± 1.34	0.201
Height (cm)	164.60 ± 4.34	0.747
Weight (kg)	54.08 ± 2.26	0.189
Dominant leg (right)	5 (100%)	-
Dominant leg muscle mass (kg)	5.54 ± 0.36	0.377

3.2. Correlations Among Average Daily Step Count, Rectus Femoris Stiffness, and Dynamic Balance

The relationships among seven-day average daily step count, rectus femoris muscle stiffness, and normalized anterior reach performance on the Y-Balance Test (YBT) were analyzed using Spearman's rank correlation.

No significant correlation was observed between average daily step count and rectus femoris muscle stiffness (ρ = −0.154, *p* = 0.805). Likewise, rectus femoris muscle stiffness was not significantly associated with normalized anterior YBT performance (ρ = −0.154, *p* = 0.805).

In contrast, a statistically significant positive correlation was identified between average daily step count and normalized anterior YBT performance (ρ = 1.000, *p* < 0.001), indicating that participants with higher habitual daily step counts demonstrated greater dynamic balance performance. Detailed correlation coefficients and descriptive statistics are presented in **Table 2**.

Table 2. Spearman's rank correlations among average step count, muscle stiffness, and dynamic balance

	Mean ± SD	Spearman's ρ	Sig. (2-tailed)
Average step count × Muscle stiffness	8211.03 ± 1774.74 / 251.00 ± 20.41	-0.154	0.805
Muscle stiffness × YBT anterior	251.00 ± 20.41 / 72.90 ± 5.73	-0.154	0.805
Average step count × YBT anterior	8211.03 ± 1774.74 / 72.90 ± 5.73	1.000*	<0.001

IV. Discussion

The present pilot study investigated the relationships among habitual physical activity, represented by seven-day average daily step count, rectus femoris muscle stiffness, and dynamic balance performance in healthy young women. The principal finding was that average daily step count demonstrated a significant positive association with anterior reach performance on the Y-Balance Test, whereas rectus femoris muscle stiffness was not significantly correlated with either habitual physical activity or dynamic balance. These findings suggest that habitual ambulatory activity may be more closely associated with functional neuromuscular performance than with the passive mechanical properties of individual muscles in healthy young adults **[8,9,16]**.

The positive association between daily step count and dynamic balance performance is consistent with the physiological adaptations induced by habitual physical activity. Walking is one of the most fundamental weight-bearing activities and requires continuous integration of sensory information, neuromuscular coordination, and postural adjustments. Repeated ambulatory activity enhances proprioceptive input, improves motor coordination, and increases the efficiency of neuromuscular control during single-leg stance **[16,19,22,29]**. Consequently, individuals who accumulate greater numbers of daily steps may develop superior postural stability and dynamic balance despite not participating in structured exercise programs.

Dynamic balance is a multifactorial construct involving coordinated interactions among the visual, vestibular, and somatosensory systems in addition to lower-extremity muscle function **[19,34]**. The anterior reach component of the Y-Balance Test requires coordinated regulation of the hip, knee, and ankle joints while maintaining the body's center of mass within a limited base of support **[20,21,27]**. Therefore, habitual physical activity may improve balance primarily through enhanced sensorimotor integration and neuromuscular efficiency rather than through isolated alterations in passive muscle mechanical properties. Previous investigations have similarly demonstrated that physically active individuals exhibit superior postural control, functional mobility, and balance performance compared with less active individuals **[22,29,31]**.

Our findings are consistent with previous reports demonstrating positive associations between physical activity and balance performance. Zhu et al. reported that objectively measured physical activity was positively associated with static balance in healthy young adults **[22]**, while Sarto et al. found that maintaining a physically active lifestyle improved both static and dynamic balance across different age groups **[31]**. Likewise, systematic reviews have concluded that regular physical activity promotes neuromuscular adaptations that enhance functional mobility and postural stability **[21,29]**. The present study extends these findings by suggesting that smartphone-derived daily step counts may serve as a practical surrogate measure for estimating dynamic balance performance in healthy young women.

In contrast, no significant association was observed between average daily step count and rectus femoris muscle stiffness. Muscle stiffness is a passive mechanical property influenced by numerous biological and biomechanical factors, including muscle architecture, connective tissue composition, hydration status, muscle fiber type distribution, fatigue, and previous exercise exposure **[13,25,26,32,33]**. Therefore, habitual walking volume alone may not provide sufficient mechanical loading to induce measurable adaptations in the passive stiffness of the rectus femoris. Furthermore, because the present participants were relatively homogeneous in age, body composition, and health status, the between-subject variability in muscle stiffness was likely limited, thereby reducing the ability to detect statistically significant associations.

Similarly, rectus femoris muscle stiffness was not significantly associated with dynamic balance performance. Although the rectus femoris plays an important role in knee extension and locomotion **[17,18]**, successful performance during the Y-Balance Test depends on coordinated activation of multiple lower-extremity muscles and efficient integration of sensory feedback rather than the passive mechanical characteristics of a single muscle **[20,21,34,35]**. Dynamic balance requires synergistic contributions from the hip abductors, ankle plantar flexors, dorsiflexors, trunk stabilizers, and central sensorimotor processing **[19,34,35]**. Consequently, passive stiffness of the rectus femoris alone is unlikely to sufficiently explain functional balance performance. Future studies incorporating comprehensive assessments of multiple lower-extremity muscles together with electromyography and motion analysis may provide a more complete understanding of the neuromuscular mechanisms underlying dynamic balance.

From a clinical perspective, the present findings suggest that smartphone-derived daily step count may represent a simple, inexpensive, and accessible digital biomarker of functional balance capacity in healthy young adults **[8,23,24]**. Because smartphone-based monitoring requires minimal equipment and can be continuously performed under free-living conditions, it may facilitate large-scale screening of physical activity and functional performance in community settings. Encouraging individuals to increase their habitual ambulatory activity may therefore represent a practical strategy for maintaining neuromuscular function and preventing future declines in postural stability **[9,16,31]**.

Several limitations should be acknowledged. First, the sample size was extremely small (n = 5), substantially limiting statistical power and external validity. The perfect correlation observed between daily step count and dynamic balance should therefore be interpreted cautiously because correlation coefficients derived from very small samples may be overestimated. Second, all participants were healthy young women, limiting the generalizability of the findings to males, older adults, and clinical populations. Third, habitual physical activity was assessed solely using average daily step count, which does not reflect exercise intensity, duration, or activity type **[12,24]**. Finally, muscle stiffness was evaluated only in the rectus femoris, which does not fully represent the complex neuromuscular interactions underlying dynamic balance **[17,35]**. Future studies should recruit larger and more diverse populations, evaluate multiple lower-extremity muscles, and integrate biomechanical and electrophysiological assessments to further elucidate the mechanisms linking habitual physical activity, muscle mechanical properties, and functional performance.

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