

Correlation Between Lumbar Core Muscle Strength and Dynamic Balance in Mountain Trekkers

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ABSTRACT

Background: Mountain trekking imposes significant demands on dynamic balance and is associated with a high incidence of fall-related injuries. Lumbar core muscle strength, reflecting the activation and control of deep stabilising muscles, may influence dynamic balance; however, its relationship in mountain trekkers remains insufficiently explored.

Methods: A cross-sectional observational study was conducted among 62 mountain trekkers (aged 15–60 years) recruited using purposive sampling. Lumbar core muscle was assessed using a pressure biofeedback unit, and dynamic balance was evaluated using the Lower Quarter Y-Balance Test. The mean of three trials in each direction was recorded. Data normality was assessed using the Kolmogorov–Smirnov Test, and associations were analysed using Spearman's rank-order correlation ($p < 0.001$).

Results: Mean lumbar core muscle strength (core activation and control) was 3.48 ± 1.19 mmHg. Mean Y-Balance composite scores were 84.29 ± 6.76 (right) and 84.51 ± 6.80 (left). A moderate positive correlation was observed between lumbar core muscle function and dynamic balance for the right ($\rho = 0.451$, $p < 0.001$) and left ($\rho = 0.462$, $p < 0.001$) limbs.

Conclusion: Lumbar core muscle strength is significantly associated with dynamic balance in mountain trekkers; however, the cross-sectional design and purposive sampling limit causal inference and generalisability.

Keywords: Y-Balance Test, pressure biofeedback, core stability, postural control

1. INTRODUCTION

Mountain trekking is a widely practiced recreational activity, with an estimated 100 million individuals visiting high-altitude regions annually (Faulhaber et al., 2020; Gardner & Hill, 2002). It involves prolonged low-to-moderate intensity physical exertion across varied terrains, including steep ascents, descents, and uneven surfaces (Bohne & Abendroth-Smith, 2007). While trekking offers recognised cardiovascular and musculoskeletal benefits (Kang, 2014), it is also associated with a considerable risk of injury.

Falls are consistently reported as the leading cause of both fatal and non-fatal incidents, particularly during descent and on technically demanding trails (Faulhaber et al., 2017).

The neuromechanical demands of trekking are heightened by terrain variability and repeated ascent–descent cycles, requiring continuous regulation of postural stability and dynamic balance (Maeo et al., 2017; Werner et al., 2023). Downhill locomotion imposes substantial eccentric loading and challenges the control of the body's centre of mass,



thereby increasing fall risk (Minetti et al., 2002; Uno et al., 2019). Effective balance under such conditions depends on the integration of sensory input with coordinated neuromuscular responses (Horak, 2006), which may be further compromised by fatigue and environmental stressors. Trail difficulty further influences injury risk, with higher-grade routes characterised by increased technical complexity and physical demands (Kreves et al., 2023). These conditions place greater demands on trunk stability and efficient force transmission, highlighting the importance of the lumbar core muscle in maintaining postural control during locomotion on uneven terrain. Muscle strength is traditionally defined as the capacity to generate force. However, in the context of spinal stability, optimal performance of the lumbar core muscle depends not only on force production but also on timely activation, coordination, and sustained contraction of deep stabilising muscles. These attributes are collectively described as core muscle function, which is essential for maintaining lumbopelvic stability during movement. The deep trunk muscles, particularly the Transversus Abdominis and Multifidus, play a critical role in spinal stability and movement control (Kibler et al., 2006; Panjabi, 1992). Evidence indicates that effective core performance relies on anticipatory activation, endurance, and coordinated neuromuscular control (Akuthota & Nadler, 2004; Hodges & Richardson, 1996). The Transversus Abdominis demonstrates feedforward activation prior to limb movement, facilitating anticipatory postural adjustments (Hodges & Richardson, 1996). While these mechanisms are distinct from maximal force generation, they are essential for efficient postural control and movement stability.

Accordingly, lumbar core muscle strength in this study is assessed using a Pressure Biofeedback Unit, which reflects the activation and control of deep stabilising muscles under low-load conditions rather than maximal force output (Cairns et al., 2000; Richardson et al., 1999). Despite these physical demands, structured pre-conditioning among trekkers remains limited (Chopda, 2022). While the association between core muscle strength and dynamic balance has been widely investigated in athletic populations (Granacher et al., 2013; Kahle & Gribble, 2009; Özmen et al., 2018), evidence specific to mountain trekkers is scarce. Therefore, the present study aims to examine the relationship between lumbar core muscle strength and dynamic balance in mountain trekkers.

2. METHODS

A cross-sectional observational study using purposive sampling was conducted among 62 mountain trekkers aged 15–60 years. All procedures involving human participants were performed in accordance with the ethical principles of the Declaration of Helsinki. Ethical approval was obtained from the Institutional Ethics Committee (E-6/162105/2364/2022, on 24/11/2022) prior to the commencement of the study. Permission for participant recruitment was obtained from mountain trekking clubs. Both male and female trekkers aged 15–60 years who were actively engaged in mountain trekking and had experience traversing varied terrains, ascending to high elevations, and carrying loaded backpacks were included. Participants across all three grades of trekking difficulty were considered. Individuals who had not participated in trekking within the past year, or who had recent fractures, soft tissue injuries, surgery within the past six months, or any known neurological, vestibular, or balance disorders were excluded. Eligible participants were provided with a participant information sheet, and the study procedure was explained. Written informed consent was obtained from the parents or legal guardians of participants aged 15–17 years who provided oral assent, and written informed consent was obtained from participants aged 18 years and above. Demographic data were recorded prior to assessment. Dynamic balance was assessed using the Lower Quarter Y-Balance Test. A Y-shaped grid was marked on the floor, and participants performed reach tasks in the anterior, posteromedial, and posterolateral directions while maintaining a single-leg stance. The stance foot was positioned with the hallux at the center of the grid. Three trials were performed in each direction for both limbs, and the mean reach distance was calculated. Limb length was measured from the anterior superior iliac spine to the ipsilateral medial malleolus in supine position. The composite score was calculated as the sum of reach distances in all three directions divided by three times the limb length and multiplied by 100. The test demonstrates excellent reliability, with inter-rater intraclass correlation coefficients (ICC) ranging from 0.85 to 0.91 and intra-rater ICC from 0.99 to 1.00 (Plisky et al., 2021). The Lower Quarter Y-Balance Test was selected due to its established validity and reliability in assessing dynamic balance in physically active populations. Lumbar core muscle strength (core activation and control) was assessed using a Pressure

Biofeedback Unit (*Chattanooga Stabilizer, DJO Global/Enovis, 2021*). In this study, lumbar core muscle strength, as referred to in the title, was operationally represented through the activation and control capacity of deep core muscles, particularly the Transversus Abdominis, during the abdominal drawing-in manoeuvre (Akuthota & Nadler, 2004; Hodges & Richardson, 1996; Richardson et al., 1999). Participants were positioned in crook lying, and the pressure cuff was placed beneath the lumbar spine and inflated to a baseline pressure of 40 mmHg. Participants were instructed to gently draw in the abdominal wall while maintaining normal breathing and avoiding pelvic or spinal movement, and to sustain the contraction for 10 s. Three trials were conducted, and the mean change in pressure (mmHg) from baseline was calculated; the highest value above baseline was considered for analysis. This measure reflects neuromuscular activation and control of deep stabilising muscles under low-load conditions, rather than maximal force production. The Pressure Biofeedback Unit has demonstrated good reliability, with inter-rater ICC of 0.87 (95% CI: 0.78–0.92) and intra-rater ICC of 0.86 (95% CI: 0.79–0.93) (Solanki & Soni, 2021). The Pressure Biofeedback Unit was selected as it provides a simple, non-invasive, and reliable method for assessing deep core muscle activation and control. Statistical analysis was performed using SPSS version 25 and Minitab version 19. Descriptive statistics were calculated and presented as mean $\pm$ standard deviation

(SD). Data normality was assessed using the Kolmogorov–Smirnov Test. As the data were not normally distributed, Spearman’s rank-order correlation coefficient (ρ) was used to examine the relationship between lumbar core muscle function and dynamic balance. The level of statistical significance was set at $\alpha = 0.05$, and a p-value < 0.05 was considered statistically significant.

3. RESULTS

A total of 62 mountain trekkers aged 15–60 years participated in the study. Descriptive statistics of participant characteristics and outcome measures are presented in Table 1. The mean lumbar core muscle strength (i.e. muscle activation and control), represented by pressure change measured using the Pressure Biofeedback Unit, was 3.48 ± 1.20 mmHg. The mean Y-Balance composite score was 84.29 ± 6.76 for the right limb and 84.51 ± 6.80 for the left limb. The relationship between lumbar core muscle strength (i.e. muscle activation and control and dynamic balance) is presented in Table 2. A moderate positive correlation was observed between lumbar core muscle strength (i.e. muscle activation and control), and Y-Balance composite scores for both limbs. The correlation was statistically significant for the right limb ($\rho = 0.451$, $p < 0.001$) and the left limb ($\rho = 0.462$, $p < 0.001$), indicating that greater core muscle activation and control were associated with better dynamic balance performance.

Table 1. Descriptive statistics of participant characteristics and outcome measures

Variable	Mean $\pm$ SD
Age (years)	30.18 $\pm$ 10.27
Weight (kg)	62.97 $\pm$ 12.41
Height (cm)	164.40 $\pm$ 9.43
BMI (kg/m ²)	23.43 $\pm$ 4.11
Lumbar core muscle strength (mmHg)	3.48 $\pm$ 1.20
Y-Balance composite right (%)	84.29 $\pm$ 6.76
Y-Balance composite left (%)	84.51 $\pm$ 6.80

Abbreviations: SD = standard deviation, mmHg = millimetres of mercury.

Table 2. Correlation of lumbar core muscle strength and Y-Balance composite score

Correlation of Lumbar Core Muscle Strength and Y Balance Composite Score			
Criteria Score		Right Y Balance Composite Score	Left Y Balance Composite Score
Lumbar core muscle strength (mmHg)	ρ	0.451**	0.462**
	p value	<0.001	<0.001

Notes: ρ = spearman's rank-order correlation coefficient; ** highly significant.

4. DISCUSSION

The present study aimed to investigate the relationship between lumbar core muscle strength and dynamic balance in mountain trekkers. Lumbar core muscle strength (i.e. muscle activation and control), as assessed in this study using a Pressure Biofeedback Unit, demonstrated a moderate positive correlation with dynamic balance, as measured by the Y-Balance Test. These findings indicate that individuals with better lumbar core muscle strength (i.e. muscle activation and control), tend to exhibit superior dynamic balance performance.

Mountain trekking involves complex neuromechanical demands, including locomotion on uneven terrain, load carriage, and repeated ascent–descent cycles, all of which require effective postural regulation. Previous literature has shown that factors such as age, sex, body mass index, and trekking difficulty influence injury patterns and balance performance (Amarowicz et al., 2019; Faulhaber et al., 2020; Krevs et al., 2023). These factors may affect postural control through alterations in proprioception, neuromuscular coordination, and biomechanical loading, thereby increasing the importance of trunk stabilisation during trekking activities.

The findings of the present study are consistent with previous research reporting weak to moderate positive associations between core muscle strength and dynamic balance in various populations (Almutairi et al., 2022; Krishna et al., 2023). From a biomechanical perspective, this relationship can be explained by the role of core musculature in providing proximal stability for distal mobility. The trunk acts as a central link in the kinetic chain, facilitating efficient force transmission and maintaining postural alignment during dynamic tasks (Kibler et al., 2006).

Neuromuscular mechanisms further support this association. Anticipatory postural adjustments,

involving pre-activation of the Transversus Abdominis and associated muscles, contribute to increased intra-abdominal pressure and spinal stiffness, thereby preparing the body for movement (Hodges & Richardson, 1996). During dynamic balance tasks, such as single-limb stance and reaching, coordinated activation of both global and local trunk muscles, including the Multifidus, Rectus Abdominis, and Obliques, assists in controlling trunk displacement and maintaining stability. In the present study, lumbar core muscle strength was operationally assessed under low-load, non-functional conditions, reflecting the ability to activate and sustain contraction of deep stabilising muscles rather than maximal force production. Within this context, the present study contributes to the existing body of evidence by demonstrating a significant association between lumbar core muscle strength and dynamic balance specifically in mountain trekkers. Indicating individuals with better lumbar core muscle strength, as reflected by the ability to activate and sustain contraction of deep stabilising muscles, may help to exhibit superior dynamic balance.

5. CONCLUSIONS

The findings of this study demonstrate a significant moderate positive association between lumbar core muscle strength and dynamic balance in mountain trekkers, indicating that individuals with better lumbar core muscle strength tend to exhibit superior balance performance. In this study, lumbar core muscle strength reflects the capacity to activate and sustain contraction of deep stabilising muscles, which plays a key role in postural control. However, due to the cross-sectional design, causal relationships cannot be established. While the study provides valuable insights, the purposive sampling may affect the generalisability of the findings.

Additionally, the assessment of lumbar core muscle strength under low-load conditions may not fully represent task-specific or high-load functional demands.

Future research involving larger and more diverse populations, as well as longitudinal or interventional designs, is recommended to further explore these relationships and their implications for injury prevention and performance in trekking populations.

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