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Differences of hamstring muscle strength between para-sprinter with upper and lower limb deficiency: Descriptive observational study

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Abstract

This study aimed to analyze the differences in hamstring muscle strength between para-sprinters with upper limb deficiency and lower limb deficiency. Participation in para-sprinting provides physical and psychosocial benefits, yet the repetitive high-intensity movements increase the risk of hamstring injuries. Previous findings showed that hamstring injuries were most likely to occur during maximal sprinting, with sprinters experiencing the highest incidence. Among 109 runners examined, 12 sustained hamstring injuries, 9 cases in sprinters and 3 in non-sprinters demonstrating that approximately 75% of these injuries occurred in sprinters. Furthermore, half of all injuries sustained by sprinters involved the hamstring muscles. As hamstring strength is essential for sprint performance and athletes with limb deficiencies rely more on their remaining muscles, examining these differences is important. This research used a quantitative observational method with a purposive sampling technique. The sample consisted of 13 para-sprint athletes belonging to National Paralympic Committee (NPC) Indonesia, comprising 7 athletes with upper limb deficiency and 6 athletes with lower limb deficiency. Hamstring muscle strength was measured isometrically using the Diers Myoline device. Data were analyzed using an independent t-test. Based on the results of the independent t-test, it can be seen that the significance value for the difference in hamstring muscle strength was 0.887, the significance value for right hamstring muscle strength was 0.782, and the significance value for left hamstring muscle strength was 0.128. The results showed no significant difference in hamstring muscle strength between the two groups ($p > 0.05$). This indicates that both groups have relatively balanced neuromuscular adaptive capabilities. These findings highlight the importance of biomechanical compensation strategies in supporting performance and injury prevention, regardless of the type of limb deficiency.

Introduction

The participation of athletes with disabilities in sports competitions provides significant contributions to improving their physical condition and strengthening their self-confidence in interacting and integrating with the wider community. Sports activities not only function as a means of physical rehabilitation, but also as a social medium capable of reducing negative stigma and improving quality of life. However, despite the substantial benefits, participation in sports competitions also carries risks, especially musculoskeletal injuries, which are often caused by excessive repetitive movements and improper techniques. This condition is exacerbated by the physical limitations possessed by disabled athletes, leading to a higher reported prevalence of injuries in this group compared to non-disabled athletes (Vitasari et al., 2023). Para Sprinting is one of the Paralympic sports with a high level of injury risk. As a highly competitive sport, sprinting requires athletes to optimize speed and strength despite their physical limitations or disabilities. The demands for maximal performance, coupled with the characteristics of intense and repetitive movements, make this category vulnerable to various types of injuries, particularly musculoskeletal injuries (Grobler et al., 2015). The demand to achieve the best performance and achievements in para-sprinting makes athletes prone to injuries, especially during centralized training. Hamstring injuries are one of the most frequently occurring types of injury in sprinters and are often

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considered common in this sport. Data indicate that the incidence of hamstring injuries continues to increase annually, with an average increase of 6.7% (Ekstrand et al., 2023). Previous findings showed that hamstring injuries were most likely to occur during maximal sprinting, with sprinters experiencing the highest incidence. Among 109 runners examined, 12 sustained hamstring injuries, 9 cases in sprinters and 3 in non-sprinters demonstrating that approximately 75% of these injuries occurred in sprinters (Sugiura et al., 2017). According to data obtained from the Physio Rehab Clinic National Paralympic Committee (NPC) Indonesia, the high incidence of lower extremity injuries, especially hamstring injuries, in athletics, particularly in running and jumping events during the 2023 ASEAN Para Games Cambodia National Training Center, was 32.1% of the total patients and had a risk of recurrent injury. This figure continued to increase during the Asian Para Games Hangzhou National Training Center and the Paralympic Paris 2024 National Training Center. Hamstring muscle strength plays an important role in athletic performance, especially in sprinting. The hamstring muscles function in knee joint flexibility and stability, and provide the propulsive force needed during the propulsion and leg swing phases in sprinting (O'Connor et al., 2022). For an athlete, muscle strength is an essential aspect that must be possessed, because every movement in sports activity demands optimal muscle strength. In sprinter athletes with limb deficiency or partial limb loss, the muscles in the intact limb must work more intensively to compensate for the function of the lost limb (Hobara et al., 2016). Para-sprinters with upper limb deficiency and lower limb deficiency may exhibit different adaptations in hamstring muscle development and use. In sprinters with upper limb deficiency, the body may need to adjust balance and movement coordination by relying more intensively on the lower extremities (Mally et al., 2015). Meanwhile, in sprinters with lower limb deficiency, the function and strength of the hamstring muscles in the remaining limb become very crucial to support stability and propulsion (Hu et al., 2023). The hamstring muscles are most active in the final phase of the swing, demonstrating the importance of these muscles in sprint performance and injury prevention (Pietraszewski et al., 2025). Research on the differences in hamstring muscle strength between these two groups is still limited, even though a deep understanding of this is important for designing appropriate training and rehabilitation programs. Therefore, the explicit objective of this study is to compare hamstring muscle strength between para-sprinters with upper limb deficiency and those with lower limb deficiency. This research is justified because information regarding the adaptation of hamstring function in different types of limb deficiencies remains scarce, despite its critical role in sprint performance and injury prevention. Findings from this study are expected to provide scientific evidence that can guide coaches, physiotherapists, and sports medicine practitioners in developing more targeted training methods and rehabilitation strategies. Currently, the main solutions applied to reduce the risk of hamstring injuries in para-sprinters involve strength training, flexibility exercises, and individualized rehabilitation programs; however, more specific data comparing different types of limb deficiencies are required to optimize these interventions. Based on this description, the research hypothesis is that there is a difference in hamstring muscle strength between para-sprinters with upper limb deficiencies and para-sprinters with lower limb deficiencies. Thus, this study is operationally directed to test for these differences through objective and standardized measurements.

Methods

This research method uses a quantitative observational approach. This study was conducted at the Physiotherapy Rehabilitation Laboratory of the National Paralympic Committee, located at Hotel Kusuma Sahid Prince Surakarta. The research was carried out in January 2025. The study was approved by the University of Sebelas Maret Ethical Committee (2025/1023) and it was carried out in accordance with the Code of Ethics of the World Medical Association also known as a declaration of Helsinki.

Participants

The population in this study consisted of para-athlete sprinters under the National Paralympic Committee Indonesia (NPC Indonesia) with upper and lower limb deficiencies. To ensure the suitability of participants with the research objectives, inclusion and exclusion criteria were applied. The inclusion criteria comprised sprinters with lower limb deficiency (T42–T44) and sprinters with upper limb deficiency (T46–T47). Meanwhile, the exclusion criteria included sprinters with acute lower extremity injuries as well as sprinters with visual or intellectual impairments. Based on demographic characteristics, the participants consisted of 10 males and 3 females. In terms of age, 12 participants were under 30 years old and 1 participant was over 30 years old. Regarding para-sprinter classification, there were 7 participants with upper limb deficiency and 6 participants with lower limb deficiency. These demographic characteristics provide a comprehensive description of the profiles and sporting backgrounds of the study participants. Subsequently, participants were recruited through coordination with the National Paralympic Committee Indonesia (NPC Indonesia) by contacting coaches and relevant personnel to obtain a list of sprinters who met the inclusion criteria.

Procedure

The sampling technique in this study was non-probability sampling with purposive sampling. This sampling technique uses certain considerations according to the desired criteria to determine the number of samples studied (Firmansyah & Dede, 2022). The sampling technique in this study was non-probability sampling with purposive sampling. This technique was applied by using specific considerations according to the predetermined criteria to determine the number of samples studied (Firmansyah & Dede, 2022). The data used in this study were primary data, which were collected directly from the participants. Data collection was carried out by measuring hamstring muscle strength using the *Diers Myoline* device. Prior to the measurement, participants received instructions and demonstrations from the therapist regarding the proper position and movement required for the test to ensure accurate and standardized results. Each participant performed the test three times, and the mean value was recorded as the final score. During the process, the therapist monitored participants closely to ensure safety and correct performance. In addition, the sample size was calculated using the Slovin formula because in determining the number of samples, it must be representative so that the research results can be generalized and accounted for. Based on this formula, with a margin of error of 25% and a population size (N) of 30, the minimum required sample size was 10. To anticipate potential dropouts and provide a reserve, the researchers added 3 participants (equivalent to 30% of the minimum sample size). A 30% reserve was chosen because the study population consisted of athletes who have a relatively higher risk of injury or unavailability during data collection. Thus, the final number of participants in this study was fixed at 13.

Diers Myoline

Diers Myoline, an innovation in isometric muscle strength measurement, successfully demonstrated that muscle strength measurement results are consistent with expected patient clinical outcomes, showing a significant correlation between muscle weakness and back pain complaints (Pietsch et al., 2021). This instrument shows validity with accuracy in isometric muscle strength measurement results such as flexion, extension, rotation, and lateral flexion in patients' trunk muscles (Schröder & Reer, 2024). *Myoline Diers* has strong reliability or dependability in measuring isometric muscle strength. This is shown by an Interclass Correlation Coefficient (ICC) of more than 0.95 in the results of back muscle flexion and extension strength measurements (Pietsch et al., 2021). The reliability of Myoline Diers is also very high, with ICC ranging between 0.76 and 0.95 in trunk muscle measurements (Schröder & Reer, 2024).This indicates that this tool provides very consistent results for isometric strength measurements, especially for muscle extension and flexion measurements. The procedure for assessing hamstring muscle strength using the Myoline Diers is carried out in several steps. First, the patient is given instructions and explanations by the therapist regarding the movements to be performed and the specific muscles to be tested, which allows the therapist to adjust the Myoline Diers settings as needed. Next, the therapist selects the program specifically designed for the hamstring muscles. The patient is then asked to sit in the appropriate position according to the exercise requirements. Once the device is programmed and the patient’s body is in the correct position, the exercise begins. The Myoline Diers provides stimulation through vibration or controlled movement that triggers deep muscle contractions. Assessment is performed after the exercise session is completed. The Myoline Diers enables the therapist to evaluate muscle imbalance by identifying which muscles are weaker or overactive, which is particularly important for addressing postural problems or asymmetries that may lead to injury. In addition, the device provides numerical data related to muscle strength, symmetry, and balance, offering objective measurements to support clinical evaluation.

Data Analysis

Data processing and analysis utilized statistical analysis software, specifically SPSS version 25. The data analysis techniques performed included: 1) Descriptive analysis; 2) Data normality test using the Shapiro-Wilk technique; 3) Homogeneity test; and 4) Hypothesis testing using an independent t-test. If the data were not normally distributed, the Mann-Whitney U test was applied as a non-parametric alternative. This test is used to compare the median values of two independent groups, thereby providing an overview of the differences between groups even when the data are not normally distributed. The level of statistical significance in this study was set at $p < 0.05$, which means that the results were considered significant if the obtained p-value was less than 0.05. Thus, decisions regarding the research hypothesis were made objectively based on statistically tested results.

Results

The characteristic data obtained in this study included gender, age, and para-sprinter group (Table 1).

Table 1
Subject characteristics.

	n	%
Sex		
Male	10	76.9
Female	3	23.1
Age		
Under 30 years old	12	92.3
Above 30 years old	1	7.7
Para-sprinter Group		
Upper Limb Deficiency	7	53.8
Lower Limb Deficiency	6	46.2

The independent t-test was conducted to compare hamstring muscle strength between para-sprinters with upper limb deficiency and those with lower limb deficiency. Levene's test was included to assess homogeneity of variances. The results are presented in Table 2.

Table 2
Independent t-test results for hamstring muscle strength.

Variables	t	df	p
Difference in Right and Left HMS	.15	11	.887
Right HMS	.29	11	.782
Left HMS	1.64	11	.128

HMS: Hamstring muscle strength.

The results indicate that there were no statistically significant differences in hamstring muscle strength between the two groups, as all p-values were greater than 0.05. The effect size (Cohen's d) also suggests a small practical difference for right and overall hamstring strength, and a medium effect for left hamstring strength. Observationally, while the left hamstring showed slightly higher variability in strength between groups, the overall hamstring performance appeared comparable between para-sprinters with upper limb deficiency and those with lower limb deficiency. These findings provide an initial insight into muscle balance among para-sprinters, which may be relevant for training and rehabilitation programs (Pietsch et al., 2021; Schröder & Reer, 2024).

Discussion

In a study conducted by Pietraszewski et al. (2020), it was found that gluteus and hamstring muscle activity significantly increased during resistance training, especially when performing sprinting movements. The average hamstring muscle activity was recorded 33% higher compared to the quadriceps muscles during sprinting. These findings affirm the importance of hamstring muscle involvement in supporting sprint performance and its crucial role in preventing injuries related to muscle imbalance (Pietraszewski et al., 2020). Based on the results of the analysis in this study, no significant difference was found in hamstring muscle strength between the para-sprinter group with upper limb deficiency and the group with lower limb deficiency. This indicates that both groups possess a relatively balanced neuromuscular adaptive capacity in responding to the load and movement patterns of sprinting. Research by Moussa et al. (2022) supports these findings by stating that athletes experiencing limb deficiency are capable of developing biomechanical compensation strategies as a form of adaptive response to physical limitations. These strategies are aimed at minimizing the impact of limb loss on the function and performance of the musculoskeletal system. In their implementation, athletes adjust movement patterns, both in daily functional activities and in the context of sports performance, by efficiently relying on the remaining limbs and other body parts (Moussa et al., 2022). This adaptation not only encompasses changes in the mechanics of movement but also involves an increase in motor coordination and neuromuscular control capabilities to compensate for lost function. Through specific and biomechanically-based training approaches, athletes can optimize the function of the available body parts to support postural stability, dynamic mobility, and efficiency in sports movements. Furthermore, this compensation strategy contributes to lowering the risk of injuries, especially those caused by improper compensation or uneven movement loads (Moussa et al., 2022). In line with this, Aslam et al.

(2025) stated that the neuromuscular adaptive capacity demonstrated by both groups of para-sprinters has significant functional relevance, as these adaptations can increase muscle strength, power production, and resistance to fatigue. These factors are keys in improving athletic performance while also playing a role in long-term injury prevention (Aslam et al., 2025).

The practical implications of these findings highlight the importance of designing well-directed training programs that focus on hamstring strengthening, improvement of neuromuscular coordination, and biomechanical efficiency to support sprint performance in athletes with disabilities. Coaches, instructors, and physiotherapists can implement structured training programs not only to increase strength but also to enhance coordination and stability, thereby reducing the risk of injuries. For example, resistance training, sprint-specific drills, and proprioceptive exercises can be integrated to help para-sprinters optimize adaptive strategies and improve athletic performance outcomes. In line with this, a recent scoping review by Tedeschi et al. (2025) demonstrated that high-speed sprinting (≥ 80–90% Vmax), when combined with eccentric training such as the Nordic Hamstring Exercise, can reduce hamstring injury risk by 56–94% while simultaneously improving muscle strength and fascicle length (Tedeschi et al., 2025). In addition, other studies emphasise that eccentric training not only triggers contractile adaptations but also changes in non-contractile and neural tissues, contributing to improved neuromuscular control and the prevention of long-term injuries (Andrews et al., 2025).

Study Limitations and Future Research Recommendations

Although this study provides valuable contributions, it has several limitations. One limitation is the relatively small sample size, which may restrict the generalization of results to the broader population of para-athletes with diverse levels of impairment and competitive backgrounds. Furthermore, the study primarily focused on hamstring muscle strength without assessing other muscle groups or considering additional biomechanical and physiological factors that could also play a role in sprint performance and injury risk. Another limitation is the cross-sectional design, which does not allow examination of how neuromuscular adaptations develop over time with long-term and progressive training interventions.

To address these limitations, future research should recruit larger and more diverse samples of para-athletes representing different types and severities of disability. Longitudinal studies are also recommended to explore the long-term effects of neuromuscular adaptations on performance and injury prevention. Additionally, further research should incorporate other relevant factors such as psychological aspects, motivational influences, and the role of assistive devices to provide a more comprehensive and holistic understanding of para-athlete performance.

Strengths and Weaknesses of the Study

This study has strengths in presenting a novel focus by comparing neuromuscular adaptations between upper and lower limb deficiency groups, thus providing important contributions to the understanding of compensation strategies in para-athletes. However, its weakness lies in the limited scope, particularly in not integrating physiological, psychological, and biomechanical aspects in a multidimensional manner, which may also significantly affect performance.

Conclusion

This study demonstrated that there were no statistically significant differences in hamstring muscle strength between para-sprinters with upper limb deficiency and those with lower limb deficiency. This indicates a relatively balanced neuromuscular adaptive capacity in both groups. Although slight variations were observed in left hamstring strength, overall performance remained comparable, suggesting that both groups are capable of developing effective compensation strategies to sustain sprint performance.

From a practical perspective, these findings highlight the importance of training programs that prioritize hamstring strengthening, neuromuscular coordination, and biomechanical efficiency to support performance and reduce the risk of injury in para-sprinters. Coaches, physiotherapists, and instructors are encouraged to integrate resistance training, sprint-specific drills, and eccentric exercises such as the Nordic Hamstring Exercise to optimize adaptation and prevent long-term injuries.

Future research is recommended to involve larger and more diverse samples of para-athletes, employ longitudinal designs, and examine other factors such as additional muscle groups, psychological aspects, and the use of assistive devices, in order to provide a more comprehensive understanding of neuromuscular adaptations in this population.

Authors Contribution

Study Design: MTN, SKP; Data Collection: MTN, SKP, RS; Statistical Analysis: MTN, SKP, RS; Manuscript Preparation: MTN, SKP, RS; Funds Collection: MTN, RS.

Ethical Approval

The study was approved by the University of Sebelas Maret Ethical Committee (2025/1023) and it was carried out in accordance with the Code of Ethics of the World Medical Association also known as a declaration of Helsinki.

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Conflict of Interest

The authors hereby declare that there was no conflict of interest in conducting this research.

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