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Ground Reaction Force Analysis in Para-Athletes with Various Impairments: A Scoping Review

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Keywords:
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Abstract

Background: Para-sport provides a new meaning of life for people with disabilities giving them the opportunity to compete nationally and globally, the achievements obtained will have a positive impact on the quality of life, social and economic. To achieve all of this requires biomechanical analysis such as ground reaction force to the specific needs of para-athletes. Objective: To determine the changes in ground reaction force (GRF) in para-athletes with various impairments. Methods: Following PRISMA guidelines, studies from 2015 to 2025 were analyzed in Scopus, PubMed, Springer, and Google Scholar. The eligible study examined para-athletes with a focus on the variable ground reaction force. Results: the 87 articles obtained 8 articles met the inclusion criteria. The participants was 97 (12.88 ± 6.97). Quality assessment (6.75 ± 0.7). This review identified significant differences in GRF between para-athletes and healthy athletes, especially in those with uTFA. Asymmetry in vertical and anterior-posterior GRFs is observed between affected and unaffected limbs in athletes with uTFA. Conclusions: This review emphasizes the importance of understanding GRF patterns in para-athletes to improve training methods, prosthetic design, and injury prevention strategies. These findings highlight the need for individualized programs that consider the unique biomechanical challenges of para-athletes.

How to Cite

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INTRODUCTION

The development of para-sports over the past few years has been very good and has achieved many achievements, and para-sports events provide a new meaning of life for people with disabilities providing opportunities for para-athletes to compete at the national and global levels (Blauwet and Willick, 2012; Youssef, 2019; Derman et al., 2023; Eugenio et al., 2024; Hjalmarsson et al., 2024). Para-athletes cover a wide range of sports, including athletics, powerlifting, badminton, cycling, boccia, swimming, archery, judo, and wheelchair basketball (Committee, 2016; Akinoğlu, Paköz and Kocahan, 2021; Derman et al., 2023). The achievements obtained by these para-athletes have a positive impact on the quality of life, social and economic (Fiorese et al., 2020; Fitri et al., 2022; Kurniawan and Samudro, 2024). Policy interventions to improve accessibility and support for para-athletes are currently still in the process of being able to maintain and improve performance (Jaarsma et al., 2014; Kasiyanto, 2023; Vitasari, Perdana and Azizah, 2023). Because para-athletes have limitations, they need to adapt to the sports they participate in and also need coaches who understand their potential and involve experts such as doctors, physiotherapists, sports science and other medical personnel to support the performance and prevention of injuries of these para-athletes.

Biomechanical analysis such as ground reaction force in para-athletes is essential in improving para-athlete performance, studying the mechanism of movement will help identify musculoskeletal imbalances or dysfunctions, diagnose postural and gait problems, optimize rehabilitation plans, prevent injuries and improve para-athlete performance tailored to the specific needs of para-athletes (Fagher, Badenhorst and Vliet, 2021; Fletcher, Gallinger and Prince, 2021; Dhaliwal and Kaur, 2022). Para-athletes have minimal impairment that can affect them for certain types of impairments, by understanding the biomechanics of their movements then coaches, and physiotherapists can develop training programs and techniques that minimize the risk of injury. Fletcher, Gallinger and Prince, (2021) Explain the need for sports-specific biomechanical models to tailor training and equipment to the needs of para-athletes and explore the differences in biomechanics in para-athletes. Therefore, data showing a broad scoping review of biomechanical patterns in tailored sports can be useful and relevant for understanding the specific needs in para-athletes.

This scoping review aims to determine the changes in ground reaction force in para-athletes with various impairments.

METHODS

This scoping review study follows all the instructions presented in the Optional Reporting Item for scoping review and the Extension Meta-Analysis (PRISMA) for scoping review to guarantee high-quality methodological reproduction.

Studies are searched in the following databases: Scopus, PubMed / MEDLINE, Springer and Google scholar from 2015 to 2025. In addition, manual searches are performed on qualified study references to complete electronic searches. For the elaboration of the search strategy used in the database, the synonyms of the terms ”Para-sport”, ”Para-athlete”, and ”biomechanics” with the search strategy: 1. ”Para-sport*” OR ”paralympic*” OR ”sports with disabilities”; 2. ”para-athlete*” OR ”disabled athletes*” OR ”athlete with impairment*” 3. ”Biomechanics” OR ”ground reaction force*” OR 4. 1 AND 2.

The following inclusion criteria are considered: 1) population: amateur or professional para-athletes; 2) ground reaction force analysis; 3) Study design: observational; 4) Results: Any biomechanical variable related to ground reaction force. No restrictions are applied to the biomechanical evaluation methods used, gender, age, year of publication, or language of the study. All sports are considered eligible for inclusion, as long as they are performed by a para-athlete or athlete with a disability. The exclusion criteria are review of articles, books, editorials, and case studies.

After completing the search in the selected database, the found titles are grouped and stored in an electronic spreadsheet for duplicate identification and exclusion. Thus, studies are selected gradually (title, abstract, and full text) with peer review.

Then, the following relevant information about the study was extracted: (1) general information (author, year of publication, and study design), (2) population characteristics (type of minimal impairment, age, and sport practiced), and (3) the ground reaction force evaluation methodology used and the results.

All included studies were evaluated by at least two independent reviewers using the Joanne Briggs Institute (JBI) for cross-sectional studies (Moola et al., 2020). The quality evaluation consists of eight items that cover areas such as study inclusion criteria, participants and settings, validity and reliability, confounding factors, and the appropriate use of statistical analysis. Each item is rated as 'yes', 'no', or 'unclear'. Any disagreements are resolved through consensus among all reviewers. Quality assessments were not used to determine study inclusion or to conduct subgroup analyses based on methodological quality or risk of bias.

RESULTS AND DISCUSSION

The search yielded 87 records after excluding duplicates, automatic filtering. Following the gradual exclusion (title, abstract, and full text), 25 titles were considered eligible. Of these, 5 studies were excluded due to the criteria of inclusion and 7 because the report was not taken and 5 studies with non-disabled athlete participants and 8 articles were obtained for review (**Figure 1.**) Thus, 8 studies that met the inclusion criteria and were analyzed (**Table 1.**).

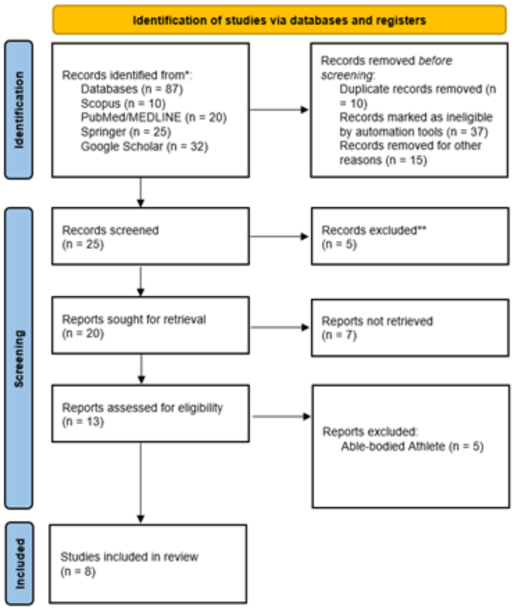

Figure 1. Flowchart to select a study.

Table 1. Study characteristics and participants

Writer	Population	Age (Years)	Study Design
Kobayashi et al., (2022)	- Individuals with unilateral transfemoral amputation (n=9) - experienced track and field para-athletes, in particular the long jump and 100m sprint and former prostheses from Ottobock, with categories ranging from 2 – 5.	25.44 ± 6.45	Observational studies with cross-sectional
Kobayashi et al., (2023)	Individuals with unilateral transfemoral amputation (uTFA) (n=15) and Individuals without amputation (n=15)	30 ± 8 uTFAs, and 30 ± 9 control groups	Observational studies with cross-sectional
Funken et al., (2015)	Para-athletes with amputees using prosthetic legs (n=3) and non-disabled athletes (n=6)		Observational studies with cross-sectional
Jabber et al., (2020)	Male Paralympic runners (n=3) and non-disabled athletic runners (n=14)	Paralympians (23 ± 6,082) and non-disabled athletes (24.7 ± 4.9)	Observational studies with cross-sectional
Sakata et al., (2020)	Runners with unilateral transfemoral amputations (n=11) Competitive athletes with experience in 100-meter racing and using their own personal running prostheses and prosthetic knee joints	29.0 ± 10.4	Observational studies with cross-sectional
Nagahara, (2021)	Men's blind sprinters elite and sub-elite pairs and their men's guide sprinters in the T11 class 100m race	34.5 ± 6.9	Observational studies with cross-sectional
Hobara, Hisano and Petrone, (2022)	Para-athletes with Unilateral Transfemoral Amputation (uTFA) (n=9), Experienced competitors in 100 m races and long jumps, using Running-Specific Prostheses (RSPs) on the affected limb and regular running shoes on the unaffected limb	30 ± 10	Observational studies with cross-sectional
R et al., (2025)	Para-athletes with cerebral palsy hemiplegia affected right (n=4) and left affected (n=5)	9:55 p.m. ± 1.8 p.m.	Observational studies with cross-sectional

Table 2. Critical Assessment Quality Assessment uses the Joanne Briggs Institute (JBI) for the assessment of cross-sectional studies.

Author	Were the criteria for inclusion in the sample clearly defined?	Were the study subjects and the setting described in detail?	Was the exposure measured in a valid and reliable way?	Were objective, standard criteria used for measurement of the condition?	Were confounding factors identified?	Were strategies to deal with confounding factors stated?	Were the outcomes measured in a valid and reliable way?	Was appropriate statistical analysis used?	Total Score
Kobayashi et al., (2022)	Yes	Yes	Yes	Yes	Yes	Unclear	Yes	Yes	7
Kobayashi et al., (2023)	Yes	Yes	Yes	Yes	Yes	Unclear	Yes	Yes	7
Funken et al., (2015)	Yes	Yes	Yes	Yes	Yes	Unclear	Yes	Yes	7
Jabber et al., (2020)	Yes	Yes	Yes	Yes	Not	Unclear	Yes	Yes	6
Sakata et al., (2020)	Yes	Yes	Yes	Yes	Yes	Unclear	Yes	Yes	7
Nagahara, (2021)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	8
Hobara, Hisano and Petrone, (2022)	Yes	Yes	Yes	Yes	Not	Not	Yes	Yes	6
Rahayu et al., (2025)	Yes	Yes	Yes	Yes	Yes	It	Yes	Yes	7

Table 3. The main findings of the studies included in the scoping review.

Author	Variables measured	Limitations	Key findings
Kobayashi et al., (2022)	Peak vertical GRF, GRF impulse components, step frequency, asymmetry ratio in GRFs, spatiotemporal parameters	Small sample size (9 participants) limits statistical strength Participants are experienced athletes, so the results may not be generalized to a wider population of individuals by amputation Individuals with amputations are unable to fully match the frequency of steps between the intact limb and the prosthetic at higher frequencies	Increased step frequency reduces the magnitude of Ground Reaction Force in individuals with transfemoral amputation ($p < 0.01$). Asymmetry in peak vertical GRF, contact time, and vertical GRF is minimized at step frequency slightly below the preferred step frequency ($p < 0.05$). Individuals with amputation are unable to match the step frequency between the intact limb and the prosthetic at a higher step frequency, leading to increased asymmetry even though GRF is reduced overall.
Kobayashi et al., (2023)	Peak vertical GRF, anteroposterior GRF, mediolateral GRF, asymmetry ratio, temporal parameters (time spent in the initial and terminal double limb stance).	Participants walk on an instrumented treadmill, which may be different from walking on the ground Small sample size of 15 participants per group, which limits statistical strength Variations in prosthetic components used by participants	The study found significant differences in GRF asymmetry between individuals with unilateral transfemoral amputation and healthy individuals, with asymmetry increasing $p < 0.01$ or $p < 0.05$ for asymmetric differences at various speeds
Funken et al., (2015)	Vertical GRF, centripetal force, spatiotemporal parameters, knee joint angle, step frequency, flight time, contact time.	Small sample size of amputated athletes Further research is needed to determine whether the findings should affect the classification, running direction, or race lineup for amputated athletes Assumption that the reduced peak vertical Ground Reaction Force limits curve sprint performance, which requires further validation	The ability of amputee athletes to generate high vertical and centripetal forces during curve sprinting depends on the location (above or below the knee) and the side (left or right) of their amputation. Athletes with amputations in the inner leg (left) are disadvantaged in generating high speeds during curve running. Kinetics of curve running with a prosthetic leg depending on the degree (above or below the knee) and the side (left or right) of the amputation.

Jabber et al., (2020)	Vertical GRF, propulsive GRF, braking GRF, initial contact (IC), toe-off (TO), flight time, contact time.	There are no considerations for variations in prosthetic type or runner's experience level; Focusing only on running barefoot, which may be different from a sprint with the help of a prosthetic.	Significant differences were observed in the GRF components (vertical, propulsive and braking force) between male Paralympic runners and athletic runners, especially in toe-off ($p < 0.05$).
Sakata et al., (2020)	Posterior anterior GRF, impulse magnitude and duration of GRF, net GRF (propulsion and braking phase)	Large variations in participants' performance levels, which can lead to variability in force application strategies and limit the ability to generalize findings Variations in the participant's prosthetic device, which can affect GRF.	Significant differences ($p < 0.05$) were observed in the GRF components (vertical force, propulsive and braking) between male Paralympic runners and athletic runners, especially during toe-offs. The study underscores the importance of understanding these strengths for prosthesis training and design.
Nagahara, (2021)	GRF variables	The sample size is small, only two pairs of blind sprinters and guides, due to the limited number of athletes competing in the T11 class	The magnitude of synchronization between blind and guide sprinters is likely to be higher in elite pairs compared to sub-elite pairs, especially during the initial acceleration phase.
	Spatiotemporal variables	Difficulties in comparing findings with previous studies, as this is the first study to investigate the biomechanics of blind sprinters and their guide sprinters	Elite guide sprinters set their sprint modalities to a greater degree compared to sub-elite guide sprinters to synchronize with blind sprinters.
Hobara, Hisano and Petrone, (2022)	Step frequency, mass specific vertical GRF, contact length, spatiotemporal parameters, running speed	The contact length of the affected limb explains only 57.7% of the highest variation in running speed, suggesting other factors may also be important This study did not fully investigate the relative importance of step frequency, meaning vertical GRF, and contact length of unaffected limbs, which may also be relevant	Contact length of the affected limb was identified as a significant factor influencing the highest running speed in para-athletes, highlighting the importance of prosthetic alignment and component selection to improve sprint performance ($p < 0.05$) Proper alignment and optimization of prosthetics is essential to maximize sprint performance in this population, as affected limbs are on mean 5.9% longer than unaffected limbs.
Rahayu et al., (2025)	Spatiotemporal parameters: scarce length, Step time, Step length, Step time, Track width, Cadence.	Small sample size that does not allow for statistical significance.	There was no statistically significant difference in spatiotemporal gait or GRF parameters between the group affected by left CP and the group affected by right CP ($p > 0.05$).
	GRF parameters: total force, mean force, max force, COP-X mean, COP-Y mean.	Lack of comparison with healthy individuals or individuals with hemiplegia to understand the magnitude of the difference.	Analysis of GRF parameters also did not reveal a statistically significant difference between the two groups ($p < 0.05$).

Characteristics of the included studies

The characteristics of the study are summarized in (**Table 1.**) The total number of participants was 97 with 47 participants (unilateral transfemoral amputation), 3 participants (Paralympic runners), 2 participants (para-athletes with sprinter guides), 9 participants (para-athletes with cerebral palsy) and 35 participants (non-disabled athletes) (Mean: 12.88; standard deviation (SD): 6.97). The median age was 27.46 years (SD: 8.36). All studies listed in the table are observational with a cross-sectional design.

Assessment of study quality

The quality assessment of the studies included is shown in **Table 2.** The overall score ranged from 6 to 8 points, with a mean score of 6.75 (SD:0.7). The results of the critical assessment quality assessment using critical appraisal from the Joanne Briggs Institute (JBI) for the assessment of cross-sectional studies (**Table 2.**) with the results of many studies (7/8: 87%) did not provide strategies to deal with confounding factors (Item 6), and there were some studies (2/8: 25%) that failed to identify confounding variables (Item 5), such as damage levels, modified test methods, or the influence of training, skills, or performance levels.

This scoping review sought to assess and synthesize the evidence related to the assessment of Ground Reaction Force (GRF) in para-athletes. Para-athletes with a variety of disorders, including those with unilateral transfemoral amputation (uTFA), cerebral palsy (CP), and Blind often exhibit unique gait patterns that differ significantly from non-disabled individuals. Studies of their biomechanics, especially GRF, are essential for improving performance and understanding the compensation mechanisms used during walking and running. This scoping review aims to determine the changes in GRF in para-athletes with various impairments.

The GRF profile of para-athletes with uTFA shows different asymmetries between the affected and unaffected limbs, especially in the vertical and anterior-posterior components ($p < 0.05$). In a study by Sakata et al., (2020), Athletes with uTFA showed consistently positive GRF in the affected limb during running, which suggests that this limb is primarily responsible for propulsion. Similarly Nagahara, (2021) noted the difference in braking force and propulsive force between the guide and the blind sprinter, revealing how these forces are distributed asymmetrically depending on the para-athlete's condition (Nagahara, 2021). At step frequencies slightly below the preferred level, asymmetry in the peak vertical GRF and contact time is minimized (Kobayashi et al., 2022). This is in line with the finding that increased step frequency reduces the magnitude of vertical GRF in individuals with transfemoral amputation (Kobayashi et al., 2023). These findings suggest that there may be an optimal step frequency that minimizes asymmetry and improves force distribution.

The impact of prosthetics on gait and GRF of choice and alignment. The choice and alignment of the prosthetic leg plays an important role in modifying the biomechanical parameters of para-athletes. In the case of uTFA athletes, prosthetic knees and legs designed for running significantly increased their vertical GRF, making the limb more efficient during the stance phase ($p < 0.05$) as well as the use of Running-Specific Prostheses (RSPs) have been associated with better symmetry in GRF and increased running time (Hobara et al., 2019; Jabber et al., 2020). According to another study, para-athletes with unilateral transfemoral amputation showed higher asymmetry in the GRF component, than athletes without amputation (Hobara et al., 2019; Jabber et al., 2020). Significant variation in GRF asymmetry at different walking speeds was noted by Funken et al., (2015), with greater asymmetry at faster walking speeds.

The compensating mechanism for walking (i.e., slower pace and longer stride time) may help preserve balance and efficiency, as evidenced by the lack of a significant difference between stride duration and force output in affected and unaffected limbs in CP para-athletes (Rahayu et al., 2025). In addition to aiding in running, uTFA athletes' use of prosthetics like the 3S80 knee unit and the running-specific foot also helps to achieve a more balanced distribution of GRF among the limbs (Hobara et al., 2019; Hobara, Hisano and Petrone, 2022).

In addition, the results suggest that the biomechanical challenges faced by para-athletes with unilateral disorders such as uTFA or CP require tailored training programs that focus on increasing step frequency, contact length, and GRF to reduce asymmetry and improve performance (Nagahara, 2021). One limitation of this review is the relatively small sample size of each study; hence, generalizing the results of the study may be difficult. Future research should concentrate on longitudinal studies with larger sample sizes to gain more thorough insights into the biomechanical adaptations of para-athletes and to find out how biomechanical adaptations affect performance and injury risk in para-athletes in the long term. Research should also look into how different equipment design and training interventions maximize biomechanical efficiency. This data will encourage the creation of strategies that improve athletes' health and performance.

CONCLUSION

This review indicates an unequal distribution of GRF, especially in para-athletes with unilateral transfemoral amputation (uTFA), cerebral palsy (CP), and visual impairment. Ground Reaction Force (GRF) among para-athletes with various disorders showed significant biomechanical differences when compared to athletes without impairment. Variations in step frequency are crucial in mitigating the notable imbalance in vertical and anterior-posterior GRFs between the affected and unaffected limbs in para-athlete uTFA. For example, it was found that increasing the frequency of alignment steps and prosthetic type is also important for maximizing GRF; Special running prostheses improve performance and symmetry. An analysis conducted on the CP of the athletes showed that there was no significant difference in GRF between the affected and unaffected limbs. This suggests that compensation mechanisms, such as changes in gait patterns, help maintain balance despite disturbances. These results show that knowledge of the GRF profile in athletes is essential for improving training techniques and prosthetic design to improve performance and prevent injury.

REFERENCES

Akinoğlu, B., Paköz, B. and Kocahan, T. (2021) 'Investigation of sitting position of paralympic wheelchair basketball players', 23(4). doi:10.37190/ABB-01920-2021-04.

Blauwet, C. and Willick, S.E. (2012) 'The Paralympic Movement : Using Sports to Promote Health , Disability Rights , and Social Integration for Athletes With Disabilities', PMRJ, 4(11), pp. 851–856. doi:10.1016/j.pmrj.2012.08.015.

Committee, I.P. (2016) 'International Standard for Eligible Impairments', (September).

Derman, W. et al. (2023) 'Incidence and burden of injury at the Tokyo 2020 Paralympic Games held during the COVID-19 pandemic : a prospective cohort study of 66045 athlete days', pp. 63–70. doi:10.1136/bjsports-2022-106234.

Dhaliwal, A.K. and Kaur, M.A. (2022) 'Role of Physiotherapy on Physical and Mental Health of the Athlete- A Review Paper', Journal of Positive School Psychology, 6(5), pp. 6401–6408.

Eugenio, C. et al. (2024) 'Exploring Implementation Barriers of Elite Parasport Programs in National Parasport Organizations Exploring Implementation Barriers of Elite Parasport Programs in National Parasport Organizations', Journal of Global Sport Management, 0(0), pp. 1–26. doi:10.1080/24704067.2024.2329221.

Fagher, K., Badenhorst, M. and Vliet, P. Van De (2021) 'Sports physiotherapy – Actions to optimize the health of Para athletes', International Journal of Sports Physical Therapy, 16(6), pp. 1376–1378. doi:10.26603/001c.29910.

Fiorese, B.A. et al. (2020) 'Biomechanics of starting, sprinting and submaximal running in athletes with brain impairment : A scoping review', Journal of Science and Medicine in Sport, 23(12), pp. 1118–1127. doi:10.1016/j.jsams.2020.05.006.

Fitri, M. et al. (2022) 'Accessibility of Inclusive Sports Facilities for Training and Competition in Indonesia and Malaysia', Sustainability, 14, pp. 1–12. doi:. https://doi.org/10.3390/su142114083.

Fletcher, J.R., Gallinger, T. and Prince, F. (2021) 'How Can Biomechanics Improve Physical Preparation and Performance in Paralympic Athletes ? A Narrative Review', Sports, 9(7), p. 89. doi:10.3390/sports9070089.

Funken, J. et al. (2015) 'Amputation Side and Site Determine Performance Capacity in Paralympic Curve Sprinting', in 34th International Conference on Biomechanics in Sports, pp. 1–4.

Hjalmarsson, E. et al. (2024) 'Determinants of Frame Running Capacity in Athletes With Cerebral Palsy to Improve Training Routines and Classification Strategies A Cross-sectional Observational Study', 103(1), pp. 79–86. doi:10.1097/PHM.0000000000002233.

Hobara, H. et al. (2019) 'Spatiotemporal parameters in sprinters with unilateral and bilateral transfemoral amputations and functional impairments', European Journal of Applied Physiology, 119(1), pp. 85–90. doi:10.1007/s00421-018-4001-1.

Hobara, H., Hisano, G. and Petrone, N. (2022) 'Biomechanical determinants of top running speeds in para-athletes with unilateral transfemoral amputation', Prosthetics and Orthotics International, 00(00), pp. 1–5. doi:10.1097/PXR.0000000000000175.

Jaarsma, E.A. et al. (2014) 'Barriers to and facilitators of sports participation for people with physical Barriers to and facilitators of sports participation for people with physical disabilities : A scoping review', Scandinavian Journal of Medicine and Science in Sports, 6(24), pp. 871–881. doi:10.1111/sms.12218.

Jabber, Y.F. et al. (2020) 'Ground Reaction Force At Athletic and Paralympic Runners – 3d _ Grfs during Ground Reaction Force At Athletic and Paralympic Runners – 3d _ Grfs during Barefoot Running', The International Journal of Engineering and Science, 8(2), pp. 11–16. doi:10.9790/1813-0802011116.

Kasiyanto, T. (2023) 'Examining Government Support for Disability Sports Development', Indonesian Journal of Disability Studies [Preprint]. doi:10.21776/ub.ijds.2023.010.04.

Kobayashi, T. et al. (2022) 'Effects of step frequency during running on the magnitude and symmetry of ground reaction forces in individuals with a transfemoral amputation', Journal of NeuroEngineering and Rehabilitation, 8, pp. 1–15. doi:10.1186/s12984-022-01012-8.

Kobayashi, T. et al. (2023) 'Ground reaction forces during double limb stances while walking in individuals with unilateral transfemoral amputation', Frontiers in Bioengineering and biotechnology, 10, p. 1041060. doi:10.3389/fbioe.2022.1041060.

Kurniawan, A. and Samudro, B.R. (2024) 'Optimizing Social and Economic Inclusion through Adaptive Sports Programs for Persons with Disabilities: A Pathway to Achieving SDGs', International Journal of Current Science Research and Review, 07(05), pp. 3066–3072. doi:10.47191/ijcsrr/V7-i5-67.

Moola, S. et al. (2020) 'Chapter 7: Scoping reviews of etiology and risk', in Aromataris, E. and Munn, Z. (eds) JBI Manual for Evidence Synthesis. JBI.

Nagahara, R. (2021) 'Kinetic and kinematic synchronization between blind and guide sprinters', Journal of Sports Sciences, 39(14), pp. 1661–1668. doi:10.1080/02640414.2021.1891739.

Rahayu, U.B. et al. (2025) 'Walking Biomechanics in Para-Athletes with Cerebral Palsy A Cross-Sectional Analysis of Spatiotemporal Parameters and Ground Reaction Forces in Indonesian Para-Athletes', cuestiones de fisioterapia, 54(2), pp. 3519–3539. doi:https://doi.org/10.48047/3kmq0t57.

Sakata, H. et al. (2020) 'Anterior-posterior ground reaction forces across a range of running speeds in unilateral transfemoral amputees', Sports Biomechanics, 00(00), pp. 1–12. doi:10.1080/14763141.2020.1822434.

Vitasari, L., Perdana, S.S. and Azizah, A.N. (2023) 'Incidence of Paralympic Sports Injuries in Para Athletes : Scoping review', in Proceedings of the International Conference on Health and Well-Being (ICHWB 2022). Atlantis Press International BV, pp. 392–409. doi:10.2991/978-94-6463-184-5.

Youssef, M.K. (2019) 'Effect of walking and aerobic exercise on physical performance and depression in cases of type 2 diabetes mellitus', pp. 142–148. doi:10.4103/ejim.ejim.