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ORIGINAL ARTICLE

THE EFFECTS OF FORWARD WALKING VERSUS BACKWARD WALKING ON PAIN LEVEL, STATIC AND DYNAMIC BALANCE AMONG COLLEGIATE ATHLETES WITH KNEE INJURIES

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ABSTRACT

Knee injuries are prevalent among collegiate athletes, necessitating effective rehabilitation strategies to restore function and minimize pain. The study aimed to compare the effects of backward and forward walking on pain levels, static, and dynamic balance in collegiate athletes with knee injuries over a 4-week intervention. Twenty-four collegiate athletes with an age of (M=22.43; SD=1.63 years) and at least 2 months of knee injury participated in the study. They were equally divided into forward walking (Group A) and backward walking (Group B) and were required to walk 3 times a week, with each session lasting 10 minutes. The results revealed that within group, both interventions showed significant pain reduction (forward walking: -22.42%; backward walking: -20.04%), and improvements in standing stork test for balance (forward: 12.87%; backward: 14.31%), anterior dynamic balance (forward: 21.32%; backward: 25.71%), posteromedial dynamic balance (forward: 33.86%; backward: 16.51%), and posterolateral dynamic balance (forward: 22.24%; backward: 26.09%) (p < 0.05). However, no significant differences were found between groups (p > 0.05). The results indicate that both interventions are equally effective on improving pain levels and balance among athletes with knee injuries. However, clinicians should consider patient preferences or specific clinical factors when selecting intervention strategies.

Keywords*: *Backward Walking, Forward Walking, Knee injury, Static Balance, Dynamic Balance

INTRODUCTION

The knee, considered the largest joint in the human body, serves critical biomechanical functions including load-bearing, shock absorption, and facilitating the flexion-extension movements essential for running, jumping, and directional changes in sport, making it pivotal for athletes participating in various sports[1,2]. Evidence from the Malaysian athletic context further supports this, with the knee consistently identified as the most frequently injured body region among local athletes across multiple sports[3]. However, it is also highly susceptible to injuries, particularly among young athletes, constituting to a staggering 2.5 million of all sports-related injuries and significantly impacting the sports community[4]. Studies of NCAA athletes across multiple sports report that ACL injury rates are notably higher during competitions compared to practices, with competition-related injury rates being approximately 5 to 10 times greater than practice rates[5,6]. Furthermore, studies revealed that women athletes exhibiting a slightly higher incidence of 2-10 times due to neuromuscular and biomechanical differences compared to men[7].However, fortunately, many knee injuries can be effectively managed with interventions like bracing and targeted rehabilitation exercises[8,9]. Among these exercises, backward walking, or retro-walking, has emerged as a therapeutic modality for knee rehabilitation, offering notable benefits such as muscle stimulation, gait improvement, and balance enhancement[10,11]. Research indicates that backward walking reduces step length, thus enhancing gait speed and lower limb endurance, while also increasing quadriceps activity and stability during the stance phase of walking[10]. Subsequently, not only that but the unique way on how the mechanism places less stress on the kneecaps and patellofemoral joints, makes it an effective and balanced exercise for knee injuries rehabilitation[10].

Conversely, forward walking stands as a low-impact method that rehabilitators infrequently use since it generates more stresses to ankle and knee joints because of the knee flexion with minimal foot movement[10]. However, experts do regard this method as a secure rehabilitation practice which gives benefits that enhance joint flexibility and help patients control weight while permitting daily activities needed for complete recovery success[11]. In addition, rehabilitation programs could benefit from forward walking through its restoration on knee joint mobility, body weight management and daily functional activities reacquisition[12]. Therefore, due to its crucial position in regular human motion forward walking becomes an essential aspect of rehabilitation because it helps patients restore physical independence and develop better knee wellness[11,12]. Collegiate athletes, defined as student-athletes enrolled in university or college-level institutions competing in organized sports[13]. Studies have revealed that NCAA athletes are particularly vulnerable to knee injuries due to high training demands, with knee injuries accounting for up to 32.9% of all sports injuries in this population[14]. Within the Malaysian context, the knee remains the most commonly injured body region among competitive athletes, highlighting the need for effective rehabilitation interventions for this population[3]. Notably, the backward walk test has demonstrated acceptable measurement properties for assessing balance and mobility in clinical populations, supporting its dual role as both an assessment and training modality[15].

However, multiple research studies have indicated that in contrast to forward walking rehabilitation exercises, there is a growing interest in backward walking as a new treatment approach, as it demonstrates potential promise for enhancing muscle activation while stabilizing gait patterns and minimizing pain symptoms[16]. Despite current existing research, there is still a lack of comparative investigations regarding how backward walking methods compare to standard forward walking protocols for collegiate athletes with knee injuries regarding their pain scales and balancing capabilities[16,17]. Consequently, addressing this gap is essential to optimize rehabilitation protocols and improve functional outcomes for injured athletes[15]. Therefore, the purpose of this study is to investigate the effectiveness of backward walking compared to forward walking as a rehabilitation intervention for collegiate athletes with knee injuries.

METHODS

Research Design

This is an experimental study with a quasi-experimental randomized pre-test and post-test group developed. The design was chosen to enable the research of cause-effect linkages. Moreover, it also allows for variable modification and the gathering of pre-test and post-test data. The independent variables in the study are forward walking and backward walking as the rehabilitation interventions, while pain levels, static and dynamic balance serve as the dependent variables. A single-blind (assessor blinded) randomized controlled trial (RCT) was performed to assess the effect of backward walking vs forward walking on pain level, static and dynamic balance in university students with knee injuries. The study was carried out in compliance with the Helsinki Declaration, and an ethics application was filed to the Sultan Idris Education University Ethics Committee. Consequently, participants' verbal and written consent was obtained.

Sampling and Randomization

In order to determine the required number of participants for the study, G*Power for Windows version 3.1.9.7 was utilized to do an a priori analysis to identify the needed quantity of subjects for the study[18]. The power analysis employed a t-test with an effect size of 0.58, and alpha and statistical power were set at 0.05 and 0.80, respectively. The power analysis determined that a minimum sample size of 10 patients every group were required, with an actual power of 0.96. Taking a 20% attrition rate into account, 12 participants were selected in each group. Two groups (backward walking and forward walking) with 12 participants each equals a total of 24 individuals. The fishbowl sample approach was utilized to assign participants to either the backward walking group (n=12) or the forward walking group (n=12).

Participants

Twenty-four collegiate athletes with a mean age of (M=22.43; SD=1.63 years) were recruited via purposive sampling, whereby participants were identified through the university's sports department and referred by coaches and team trainers based on the eligibility criteria[13]. Among the participants, there were 17 males (70.8%) and 7 females (29.2%), backward walking, 12 (50%), and forward walking, 12 (50%). The inclusion criteria for participant eligibility for participation were Sultan Idris Education University collegiate athletes aged 19 to 27 years old, either gender, as it corresponds to the typical university enrolment period and represents the peak competitive years for collegiate athletes, during which the risk of sports-related knee injuries is highest[5,14]. The participants were required to have at least with 2 months of knee injuries or knee related issues. Additionally, they were required to be able to interpret and follow the research procedure. Participants that did not meet the criteria were excluded from this study.

Study Interventions
The participants were randomly assigned to either the forward walking group (n=12) or the backward walking group (n=12). Each intervention session lasted for a standardized duration of 10 minutes, with a total of 12 sessions conducted over 4 weeks, amounting to 3 sessions per week[11]. The intensity of the intervention was self-paced, allowing participants to walk at their preferred speed and intensity. The participants were required to undergo two tests to assess their stability, namely the Y-balance test for dynamic balance and the standing stork test for static balance[19-21]. Upon completion of the test, the participants were required to rate their pain levels using the numeric pain rating scale (NPRS).

Outcome Measures
The Visual Analog Scale (VAS) was employed as the outcome measurement tool to assess pain intensity levels, specifically serving as the basis for the Numeric Pain Rating Scale (NPRS), whereby participants rated their pain levels on a scale from 0 to 10, where 0 indicated "no pain" and 10 represented the "worst possible pain"[19]. The Intraclass Correlation Coefficient (ICC) for the VAS scale was found to be 0.97, indicating strong reliability[19]. The static balance was evaluated using the standing stork test, which involved a proper warm-up protocol followed by participants placing one hand on their hips and one foot on the inside knee of the opposing leg. Participants elevated their heel and endeavored to maintain balance for as long as possible. The duration for which participants successfully maintained balance was used to calculate their score. The standing stork test has demonstrated acceptable test-retest reliability for assessing static balance in healthy young adults[20]. The dynamic balance was measured using the Y-Balance test, wherein participants followed a specific sequence to perform balancing tests in three directions for both the right and left legs: anterior, posteromedial, and posterolateral. This test assesses the distance reached by participants while maintaining balance, providing insights into dynamic stability and neuromuscular control. The ICC for the Y-Balance test ranged from 0.83 to 0.96, which indicated good reliability[21]. All outcome measures were administered by a single trained assessor, who was blinded to group allocation to minimize assessment bias and ensure consistency across all testing sessions. The assessor underwent a familiarization session prior to data collection to standardize testing procedures. Outcome measurements were conducted at two time points: at baseline prior to intervention commencement (T0, Week 0) and immediately following the completion of the 4-week intervention period (T1, Week 4).

Statistical Analysis
The data was analyzed using IBM SPSS Statistics for Windows, Version 25.0 (Armonk, NY: IBM Corp). The means and standard deviations were estimated for continuous variables whereas frequency distributions were generated for categorical variables. A parametric statistical approach, the Paired sample T-test was utilized to assess the effects of backward walking with forward walking on pain level, static and dynamic balance in college athletes with knee injuries. The statistical significance was set at $p < 0.05$ (two-tailed).

RESULTS

The Descriptive Statistics of Participants Demography

Table 1 presents the baseline demographic characteristics of all (*n*=24) participants recruited for this study. The participants had a mean age of (*M*=22.43; *SD*=1.63 years), with a range of 5 years, reflecting a homogeneous age group consistent with the collegiate athlete population. The mean height and weight of participants were (*M*=171.62; *SD*=6.92 cm) and (*M*=67.52; *SD*=11.60 kg) respectively, with weight showing the greatest variability among all anthropometric measures. The mean BMI was (*M*=22.78; *SD*=2.49 kg/m^2), which falls within the normal healthy weight range according to the World Health Organization (WHO) classification, suggesting that obesity was not a confounding factor in this study. Based on the lower anthropometry characteristics, the mean right leg length was (*M*=92.78; *SD*=3.38 cm) and mean left leg length was (*M*=92.99; *SD*=3.11 cm), indicating bilateral symmetry among participants. In terms of gender distribution, the sample comprised (*n*=17) males (70.8%) and (*n*=7) females (29.2%), with (*n*=12) participants equally allocated to each intervention group, the forward walking group (*n*=12, 50%) and the backward walking group (*n*=12, 50%).

Table 1a: Baseline Demographic Characteristics of Participants (n=24)

Variables	Mean (*M*)	Standard Deviation (*SD*)	Range
Age (years)	22.43	1.63	5
Height (cm)	171.62	6.92	22
Weight (kg)	67.52	11.60	40

Table 1b: Baseline Demographic Characteristics of Participants (n=24

BMI (kg/m^2)	**22.78**	**2.49**	**9.6**
Right Leg Length (cm)	92.78	3.38	11.0
Left Leg Length (cm)	92.99	3.11	12.0

The Descriptive Statistics of Pre and Post-Test

Table 2 presents the pre and post-test outcome measures for both intervention groups following the 4-week intervention period. For pain levels, the forward walking group demonstrated a reduction in mean NPRS score from (*M*=6.69; *SD*=0.87) at baseline to (*M*=5.19; *SD*=0.72) post-intervention, representing a decrease of 1.50 points. Similarly, the backward walking group recorded a reduction in mean NPRS score from (*M*=5.54; *SD*=0.92) at baseline to (*M*=4.43; *SD*=0.87) post-intervention, representing a decrease of 1.11 points. These findings suggest that both interventions contributed to clinically meaningful reductions in pain levels among collegiate athletes with knee injuries (*See Figure 1*). With regard to static balance, the forward walking group demonstrated an improvement in mean Stand Stork Test scores from (*M*=13.67; *SD*=0.66 seconds) at baseline to (*M*=15.43; *SD*=1.13 seconds) post-intervention, reflecting an improvement of 1.76 seconds. The backward walking group similarly showed improvement from (*M*=14.61; *SD*=0.67 seconds) at baseline to (*M*=16.70; *SD*=1.45 seconds) post-intervention, reflecting an improvement of 2.09 seconds, indicating that both groups demonstrated enhanced static balance following the intervention period (*See Figure 2*). With respect to dynamic balance as measured by the Y-Balance Test, improvements were observed across all three directions in both groups. For the anterior direction, the forward walking group improved from (*M*=58.67; *SD*=9.61 cm) to (*M*=71.18; *SD*=5.38 cm), while the backward walking group improved from (*M*=59.27; *SD*=9.64 cm) to (*M*=74.51; *SD*=5.80 cm) (*See Figure 3*). For the posteromedial direction, the forward walking group improved from (*M*=58.86; *SD*=4.38 cm) to (*M*=78.79; *SD*=9.13 cm), and the backward walking group improved from (*M*=73.04; *SD*=3.91 cm) to (*M*=85.10; *SD*=5.65 cm) (*See Figure 4*). For the posterolateral direction, the forward walking group improved from (*M*=63.61; *SD*=10.42 cm) to (*M*=77.76; *SD*=4.64 cm), while the backward walking group improved from (*M*=68.33; *SD*=12.02 cm) to (*M*=86.16; *SD*=5.73 cm) (*See Figure 5*). Overall, both groups demonstrated consistent improvements in dynamic balance across all three directions of the Y-Balance Test following the 4-week intervention.

Table 2: Pre and Post-Test Outcome Measures by Forward and Backward Walk Groups (n=24)

Variables	Forward Walking (*n*=12) Pre M ± SD	Forward Walking (*n*=12) Post M ± SD	Backward Walking (*n*=12) Pre M ± SD	Backward Walking (*n*=12) Post M ± SD
NPRS	6.69 ± 0.87	5.19 ± 0.72	5.54 ± 0.92	4.43 ± 0.87
Stand Stork Test (sec)	13.67 ± 0.66	15.43 ± 1.13	14.61 ± 0.67	16.70 ± 1.45
Y-Balance Anterior (cm)	58.67 ± 9.61	71.18 ± 5.38	59.27 ± 9.64	74.51 ± 5.80
Y-Balance Posteromedial (cm)	58.86 ± 4.38	78.79 ± 9.13	73.04 ± 3.91	85.10 ± 5.65
Y-Balance Posterolateral (cm)	63.61 ± 10.42	77.76 ± 4.64	68.33 ± 12.02	86.16 ± 5.73

Table 3 presents the paired sample t-test results for the backward walking group, comparing pre-test and post-test outcomes across all measured variables. A statistically significant reduction in pain levels was observed, with mean NPRS scores decreasing from (*M*=5.54; *SD*=0.92) at baseline to (*M*=4.43; *SD*=0.87) post-intervention, yielding a mean difference of (M=1.11; SD=1.54) ($t(11) = 2.51$, $p = 0.029$). With regard to static balance, the Stand Stork Test demonstrated a significant improvement, with mean scores increasing from (*M*=14.61; *SD*= 0.67 seconds) to (*M*=16.70; *SD*=1.45 seconds), reflecting a mean difference of (*M*=-2.09; *SD*=1.39 seconds) ($t(11) = -5.22$, $p < 0.001$). For dynamic balance, significant improvements were observed across all three directions of the Y-Balance Test. The anterior direction improved from (*M*=59.27; *SD*=9.64 cm) to (*M*=74.51; *SD*=5.80 cm), with a mean difference of (*M*=-15.24; *SD*=13.07 cm) ($t(11) = -4.04$, $p = 0.002$). The posteromedial direction improved from (*M*=73.04; *SD*=3.91 cm) to (*M*=85.10; *SD*=5.65 cm), with a mean difference of (*M*=-12.06; *SD*=6.41 cm) ($t(11) = -6.50$, $p < 0.001$). The posterolateral direction improved from (*M*=68.33; *SD*=12.02 cm) to (*M*=86.16;

SD=5.73 cm), with a mean difference of (*M*=-17.83; *SD*=11.25 cm) ($t(11) = -5.50$, $p = 0.001$). These results indicate that the backward walking intervention produced statistically significant improvements across all outcome measures, including pain levels, static balance, and dynamic balance in all three directions.

Table 4 presents the paired sample t-test results for the forward walking group, comparing pre-test and post-test outcomes across all measured variables. A statistically significant reduction in pain levels was observed, with mean NPRS scores decreasing from (*M*=6.69; *SD*=0.87) at baseline to (*M*=5.19; *SD*=0.72) post-intervention, yielding a mean difference of (*M*=1.50; *SD*=0.63) ($t(11) = 8.24$, $p < 0.001$). With regard to static balance, the Stand Stork Test demonstrated a significant improvement, with mean scores increasing from (*M*=13.67; *SD*=0.66 seconds) to (*M*=15.43; *SD*=1.13 seconds), reflecting a mean difference of (*M*=-1.76; *SD*=1.11 seconds) ($t(11) = -5.50$, $p < 0.001$). For dynamic balance, significant improvements were observed across all three directions of the Y-Balance Test. The anterior direction improved from (*M*=58.67; *SD*=9.61 cm) to (*M*=71.18; *SD*=5.38 cm), with a mean difference of (*M*=-12.51; *SD*=11.29 cm) ($t(11) = -3.84$, $p = 0.003$). The posteromedial direction improved from (*M*=58.86; *SD*=4.38 cm) to (*M*=78.79; *SD*=9.13 cm), with a mean difference of (*M*=-19.93; *SD*=8.28 cm) ($t(11) = -8.33$, $p < 0.001$). The posterolateral direction improved from (*M*=63.61; *SD*=10.42 cm) to (*M*=77.76; *SD*=4.64 cm), with a mean difference of (*M*=-14.16; *SD*=11.12 cm) ($t(11) = -4.41$, $p = 0.001$). These results indicate that the forward walking intervention produced statistically significant improvements across all outcome measures, including pain levels, static balance, and dynamic balance in all three directions.

Table 3: The Paired Sample T-Test outcome for The Backward Walking Group

Variables	Mean Diff ± SD	*t*	*df*	*p*
NPRS	1.11 ± 1.54	2.51	11	0.029
Stand Stork Test (sec)	-2.09 ± 1.39	-5.22	11	<0.001
Y-Balance Anterior (cm)	-15.24 ± 13.07	-4.04	11	0.002
Y-Balance Posteromedial (cm)	-12.06 ± 6.41	-6.50	11	<0.001
Y-Balance Posterolateral (cm)	-17.83 ± 11.25	-5.50	11	0.001

Table 4: The Paired Sample T-Test outcome for The Forward Walking Group

Variables	Mean Diff ± SD	*t*	*df*	*p*
NPRS	1.50 ± 0.63	8.24	11	<0.001
Stand Stork Test (sec)	-1.76 ± 1.11	-5.50	11	<0.001
Y-Balance Anterior (cm)	-12.51 ± 11.29	-3.84	11	0.003
Y-Balance Posteromedial (cm)	-19.93 ± 8.28	-8.33	11	<0.001
Y-Balance Posterolateral (cm)	-14.16 ± 11.12	-4.41	11	0.001

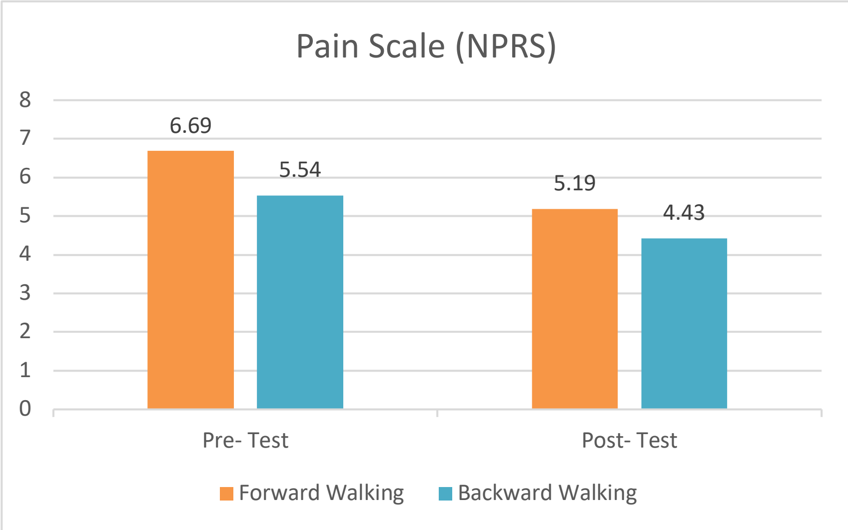

Figure 1: *The Mean NPRS Score for pre- test and post- test for both groups.*

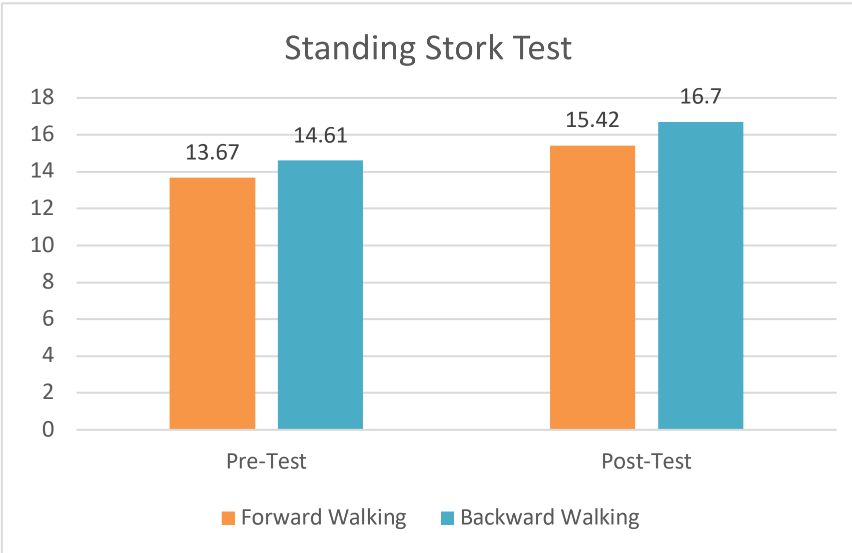

Figure 2: *The mean standing stork test time for pre- test and post- test for both groups.*

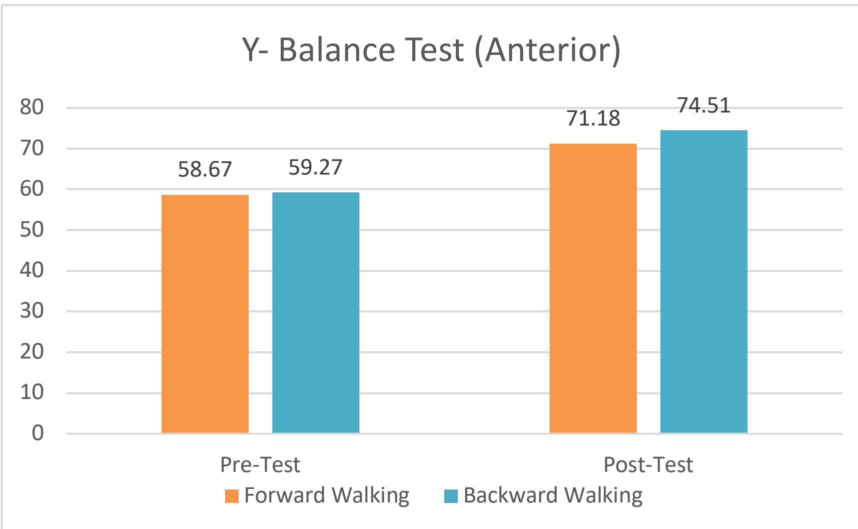

Figure 3: *The mean Y-Balance test (Anterior) for pre- test and post- test for both groups.*

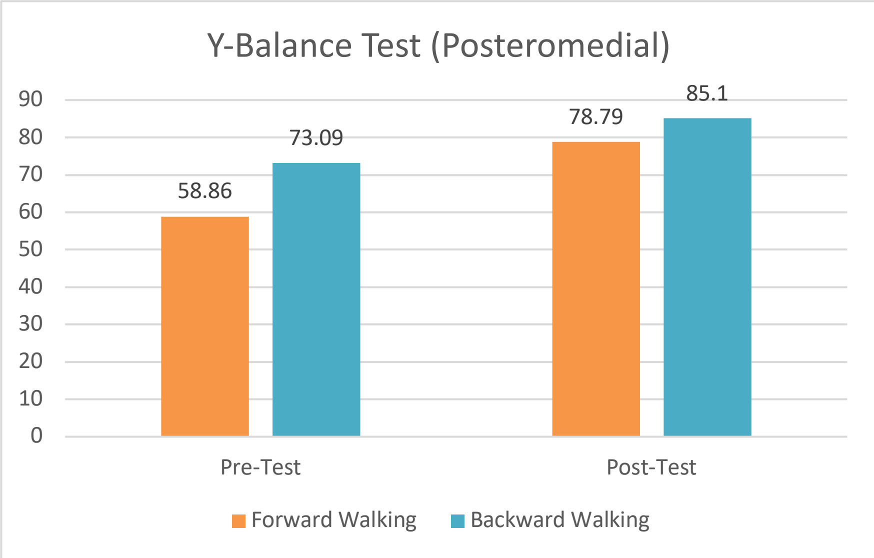

Figure 4: *The mean Y- Balance test (Posteromedial) for pre-test and post-test for both groups.*

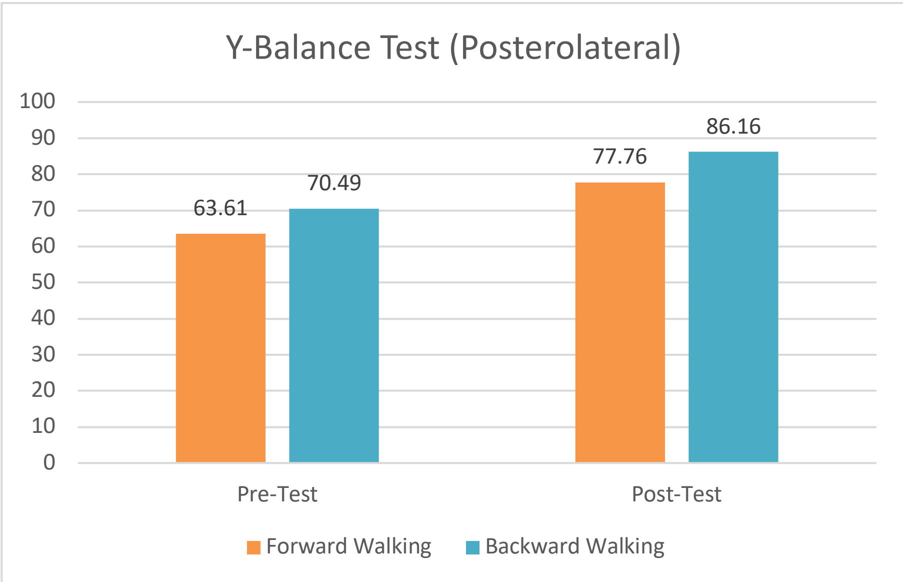

Figure 5: *The mean Y-Balance test (Posterolateral) for pre- test and post- test for both groups.*

DISCUSSION

The investigation assessed the effects of backward and forward walking on pain levels as well as static and dynamic balance among collegiate athletes with knee injuries with a structured 4-week intervention. Both the forward walking and the backward walking procedures showed significant improvement in the numeric pain rating scale (NPRS) assessments and static and dynamic balance measurements across the 4-week investigation period from the pre to post-test. The subjects in the forward walking group achieved a greater mean NPRS reduction of (M=1.50; SD=0.63) ($t(11) = 8.24$, $p < 0.001$), while the backward walking group showed a mean NPRS reduction of (M=1.11; SD=1.54) ($t(11) = 2.51$, $p = 0.029$). The results showed both groups achieved better NPRS scores along with enhanced static balance in addition to dynamic balance in the pre-test to post-test period. Subjects in the forward walking group achieved significant decreases in NPRS averaging 1.50 (SD=0.63), alongside significant improvements in static and dynamic balance assessments. Similarly, the backward walking group participants achieved both a notable decline in NPRS scores and improvements in static and dynamic balance test results.

The findings of this research are in line with previous findings as it reports significant improvement in the knee muscle function improvements after patients received forward and backward walking interventions[22]. Furthermore, the neuromuscular control of knee joints together with proprioceptive abilities improved when patients train with backward walking as opposed to forward walking, contributing to better functional outcomes[23]. Similarly, in a randomized control trial, the arthritis patients demonstrated improved static knee stability through backward walking and reduction on the NPRS scores compared to the control group[22]. Additionally, the essential element for dynamic stability together with postural control referred to as the lower limb proprioception shows significant improvement through backward walking interventions[16]. Moreover, it has been observed that backward walking practices demonstrate both knee joint strain reduction features along with quad muscles strengthening capabilities allowing it to be suitable for rehabilitation uses according to previous studies[24]. Consequently, backward walking also creates high proprioceptive demands hence improving postural stability together with dynamic balance particularly in population groups with musculoskeletal conditions[25]. In addition, backward walking has been shown to reduce the external knee adduction moment, indicating decreased medial compartment loading that may further support its role in knee rehabilitation[26].

The present study demonstrates that forward and backward walking exercises may enhance the rehabilitation of knee injuries but it fails to demonstrate substantial differences in pain reduction capabilities or balance improvements between them. This could be attributed to external influencing factors including individual biomechanics, muscle activation patterns, and participant compliance towards the training methods, all of which may have influenced the outcomes[11,27]. Previous studies hint that backward walking may be superior in improving static and dynamic balance[28]. This is consistent with previous literature suggesting that both modalities activate similar neuromuscular mechanisms, albeit through different biomechanical pathways[29].

Given the growing body of evidence supporting the use of backward and forward walking in knee rehabilitation, future research should focus on long-term outcomes and the mechanisms through which backward walking influences knee rehabilitation outcomes. Furthermore, researching the effectiveness of integrating forward walking together with backward walking exercises in one training program may allow researchers to understand on how to enhance muscle strength and knee stability further[10-12]. Additionally, clinical practitioners should also integrate backward walking exercises into rehabilitation programs by comprehending the neuromuscular adaptations along with biomechanical efficiency and proprioceptive feedback for the knee injury patients. Overall, the findings of this study support the incorporation of both forward and backward walking as equally effective rehabilitation interventions for collegiate athletes with knee injuries, and clinicians may select either modality based on patient preference or specific clinical considerations.

CONCLUSIONS

This research findings demonstrate the relationship between forward walking exercise and backward walking exercises regarding pain levels and static as well as dynamic balance improvement for collegiate athletes with knee injuries. The outcome data reveals that both forward walking and backward walking demonstrated significant improvements in pain measurement and static and dynamic balance performance within each group, however no statistically significant differences were found between the two interventions ($p > 0.05$). The findings indicate that both forward walking and backward walking represent equally valid therapeutic strategies during the knee injury recovery period, and clinicians may select either modality based on patient preference or specific clinical considerations. This research will lead to further studies about the precise ways different walking techniques affect athlete pain perceptions together with balance performance which can help develop customized rehabilitation programs for better outcomes.

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REFERENCES

1. Harput G. Kinesiology of the knee joint. In: Elsevier eBooks. 2020. p. 393–410. doi:10.1016/b978-0-12-812162-7.00022-9.

2. Zhang M, Chen Z, Li G, Mak AFT, Roberts VC. Knee joint biomechanics in physiological conditions and how pathologies can affect it: a systematic review. Appl Bionics Biomech. 2020; 2020:1–19. doi:10.1155/2020/7451683.

3. Jabbar MAJ, Chandran J, Yi Yuan O, Masilamani R. Prevalence of musculoskeletal injuries among

taekwondo players in Malaysia. Malays J Public Health Med. 2021;21(2):382-393. doi:10.37268/mjphm/vol.21/no.2/art.1072.

4. Ahmad DJ, Reefi AN, Alzahrani TS, Aljethaily AA, Almansour AF, Aldaghmani MS, et al. Strategies for X-ray utilization in the evaluation of knee injuries. Int J Community Med Public Health. 2023;11(1):485–490. doi:10.18203/2394-6040.ijcmph20233943.

5. Dewig D, Boltz A, Moffit R, Rao N, Collins C, Chandran A. Epidemiology of anterior cruciate ligament tears in National Collegiate Athletic Association athletes: 2014/2015-2018/2019. Med Sci Sports Exerc. 2023; 56:29–36. doi:10.1249/mss.0000000000003281.

6. Dewig D, Chandran A, Boltz A, Robison H, Collins C, Blackburn T. Epidemiology of anterior cruciate ligament injuries in National Collegiate Athletic Association athletes: 2014/15–2018/19. Med Sci Sports Exerc. 2022. doi:10.1249/01.mss.0000883056.32529.7d.

7. Marmura H, Bryant D, Getgood A. Sex differences and ACL injuries. Br J Sports Med. 2021; 55:1313–1314. doi:10.1136/bjsports-2021-104134.

8. Mavrovouniotis A, Potoupnis M, Sayegh F, Galanis N, Argiriadou E, Mavrovouniotis F. The effects of exercise on the rehabilitation of knee ligament injuries in athletes. Eur J Phys Educ Sport Sci. 2019; 5:2019–2019. doi:10.46827/EJPE.V0I0.2599.

9. He X. Observation on the rehabilitation effect of athletes with anterior cruciate ligament injury of the knee based on multidisciplinary combined nondrug therapy. J Healthc Eng. 2022; 2022:1–5. doi:10.1155/2022/9528354.

10. Cha H, Kim T, Kim M. Therapeutic efficacy of walking backward and forward on a slope in normal adults. J Phys Ther Sci. 2016;28(6):1901–1903. doi:10.1589/jpts.28.1901.

11. Alghadir AH, Anwer S, Sarkar B, Paul AK, Anwar D. Effect of 6-week retro or forward walking program on pain, functional disability, quadriceps muscle strength, and performance in individuals with knee osteoarthritis: a randomized controlled trial. BMC Musculoskelet Disord. 2019;20(1). doi:10.1186/s12891-019-2537-9.

12. Parikh P, Desai D. Effectiveness of forward walking versus retro walking on balance, gait speed and lower body functional strength among the elderly population: a comparative study. Int J Health Sci Res. 2022. doi:10.52403/ijhsr.20220433.

13. Lam KC, Thomas SS, Valier ARS, McLeod TCV, Bay RC. Previous knee injury and health-related quality of life in collegiate athletes. J Athl Train. 2017;52(6):534–540. doi:10.4085/1062-6050-50.5.01.

14. Kay M, Register-Mihalik J, Gray A, Djoko A, Dompier T, Kerr Z. The epidemiology of severe injuries sustained by National Collegiate Athletic Association student-athletes, 2009–2010 through 2014–2015. J Athl Train. 2017;52(2):117–128. doi:10.4085/1062-6050-52.1.01.

15. Hao J, Pu Y, He Z, Remis A, Yao Z, Li Y. Measurement properties of the backward walk test in people with balance and mobility deficits: a systematic review. Gait Posture. 2024; 110:1–9. doi:10.1016/j.gaitpost.2024.02.018.

16. Wu Y, Lei C, Huangfu Z, Sunzi K, Yang C. Effect of backward walking training on knee osteoarthritis: protocol of a systematic review and meta-analysis. BMJ Open. 2020;10(10):e040726. doi:10.1136/bmjopen-2020-040726.

17. Dar SM, Nur Syuhada Mohd Faudzy. Habits Of Donning Headscarf: Correlation Between Neck Range of Motion and Proprioception Among Female Students of IIUM Kuantan Campus, Malaysia. MJPHM [Internet]. 2024 Dec. 28 ;24(3):63-70. Available from: https://mjphm.org/index.php/mjphm/article/view/2632.

18. Kang H. Sample size determination and power analysis using the G*Power software. J Educ Eval Health Prof. 2021;18. doi:10.3352/jeehp.2021.18.17.

19. Bijur P, Silver W, Gallagher E. Reliability of the visual analog scale for measurement of acute pain. Acad

Emerg Med. 2001;8(12):1153–1157. doi:10.1111/j.1553-2712.2001.tb01132.x.

20. Panta K, Arulsingh W, Raj JO, Sinha M, Rahman M. A study to associate the Flamingo Test and the Stork Test in measuring static balance on healthy adults. Foot Ankle Online J. 2015;8(3):4. doi: 10.3827/faoj.2015.0803.0004.

21. Takahashi H, Igawa T, Ito S, Urata R, Suzuki K, Ito R, et al. An examination of the intra-rater reliability of the Y Balance test for high school female athletes. J Phys Ther Sci. 2025; 37:1–5. doi:10.1589/jpts.37.1.

22. Sedhom MG. Backward walking training improves knee proprioception in non-athletic males. Int J Physiother. 2017;4(1). doi:10.15621/ijphy/2017/v4i1/136161.

23. Chen Z, Ye X, Wang Y, Shen Z, Wu J, Chen W, et al. The efficacy of backward walking on static stability, proprioception, pain, and physical function of patients with knee osteoarthritis: a randomized controlled trial. Evid Based Complement Alternat Med. 2021; 2021:1–9. doi:10.1155/2021/5574966.

24. Klemenov A. Possibilities with backward walking for knee pathology (literature review). Genij Ortopedii. 2021;27(1):128–131. doi:10.18019/1028-4427-2021-27-1-128-131.

25. Etefagh F, Jamshidi A, Nickjoo A. Walking backwards improves high school female athletes' balance. J Res Med Dent Sci. 2017; 5:46–48. doi:10.24896/JRMDS.V5I1.245.

26. Zhang M, Pang J, Lu J, Kang M, Chen B, Jones R, et al. The immediate effect of backward walking on external knee adduction moment in healthy individuals. J Healthc Eng. 2022;2022.doi:10.1155/2022/4232990.

27. Nurhanisah M, Sulaiman R, Khairul Manami, Che me R. A Survey on Musculoskeletal Pain and Discomfort Among Industrial Workers. MJPHM [Internet]. 2023 Dec. 28 ;23(3):235-44. Available from: https://mjphm.org/index.php/mjphm/article/view/1902.

28. Goonasegaran A, Suhaimi A, Mokhtar A. Retro-walking improves symptoms, pain, and function in primary knee osteoarthritis: a randomised control trial. J Sports Med Phys Fitness. 2020. doi:10.23736/S0022-4707.20.11686-4.

29. Zych M, Cannariato A, Bonato P, Severini G. Forward and backward walking share the same motor modules and locomotor adaptation strategies. Heliyon. 2021;7:e07864. doi:10.1016/j.heliyon.2021.e07864.