Unravelling the Impact of Physical Activity on Postural *Stability: An Experimental Study of University Students*

Authors

Firdaus Hendry Prabowo Yudho [1,2]
Fahmy Fachrezzy [1]
Firmansyah Dlis [1]

[1] Universitas Negeri Jakarta
[2] Universitas Suryakancana

Corresponding author:
Firdaus Hendry Prabowo Yudho
firdaushendryprabowoyudho_9904921035@mhs.unj.ac.id

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Abstract

Introduction: This study examined the effects of physical education-based physical activity interventions on postural stability in adolescent females and evaluated the performance of a novel inclinometer sensor.
Methods: Thirty-five healthy, physically active female students ($\bar{x}$ age = 18.9 ± .83 years; BMI = 20.9 ± 4.36) participated. Postural stability was measured during 10-second trials under bipedal, unipedal, and tiptoe stance conditions. An inclinometer sensor recorded tilt angles and body sway using the mean and standard deviation from 100 readings per test.
Results: Significant improvements in postural stability were found following the 16-session intervention. The most notable gains occurred in the sagittal plane during bipedal ($p < .001$, effect size = .911) and unipedal stances ($p < .001$, effect size = .959). Tiptoe stance showed the strongest overall improvement in both the sagittal ($p < .001$, effect size = .857) and frontal planes ($W = 613$, $p < .001$). The Friedman test indicated statistically significant changes across all standing conditions ($p < .001$).
Discussion: These findings confirm that structured physical activity can significantly enhance postural control and stability, supporting its role in physical education curricula. Results align with prior research on sports and balance-focused training.
Conclusion: Participants demonstrated clear improvements in postural stability, especially in the sagittal plane, progressing toward a more upright posture. These changes were precisely captured using a novel inclinometer sensor, underscoring its potential as an effective tool for monitoring posture in both educational and clinical environments.

Keywords

Body Sway, Inclinometer Sensor, Physical Activity, Physical Education, Postural Stability

Resumen

Introducción: Este estudio examinó los efectos de las intervenciones de actividad física basadas en la educación física sobre la estabilidad postural en mujeres adolescentes y evaluó el rendimiento de un nuevo sensor inclinómetro.
Métodos: Participaron treinta y cinco estudiantes mujeres sanas y físicamente activas (edad media = 18.9 ± 0.83 años; IMC = 20.9 ± 4.36). La estabilidad postural se midió durante pruebas de 10 segundos en posturas bipedal, unipodal y de puntillas. Un sensor de inclinómetro registró los ángulos de inclinación y el balanceo corporal utilizando la media y la desviación estándar de 100 lecturas por prueba.
Resultados: Se observaron mejoras significativas en la estabilidad postural tras la intervención de 16 sesiones. Las mejoras más notables se presentaron en el plano sagital durante las posturas bipedal ($p < .001$, tamaño del efecto = .911) y unipodal ($p < .001$, tamaño del efecto = .959). La postura de puntillas mostró la mayor mejora global tanto en el plano sagital ($p < .001$, tamaño del efecto = .857) como en el plano frontal ($W = 613$, $p < .001$). La prueba de Friedman indicó cambios estadísticamente significativos en todas las condiciones de postura ($p < .001$).
Discusión: Estos hallazgos confirman que la actividad física estructurada puede mejorar significativamente el control y la estabilidad postural, respaldando su integración en los programas de educación física. Los resultados coinciden con investigaciones previas sobre deportes y entrenamientos centrados en el equilibrio.
Conclusión: Las participantes mostraron mejoras claras en la estabilidad postural, especialmente en el plano sagital, avanzando hacia una postura más erguida. Estos cambios fueron captados con precisión mediante un sensor de inclinómetro novedoso, lo que destaca su potencial como herramienta eficaz para el monitoreo postural en entornos educativos y clínicos.

Palabras clave

Actividad Física, Balanceo Corporal, Educación Física, Estabilidad Postural, Sensor de Inclinómetro

Introduction

Balance is defined as the capability of the musculoskeletal system to sustain a stable posture (Humphreys, 2008). Human postural stability is often evaluated through a series of posturographic tests conducted during quiet upright standing (Gržinič Frelih et al., 2017), that refers to the process of achieving, maintaining, or restoring a balanced state during various activities, (Rubin et al., 2023) or the capability to maintain an upright posture during a static stance or to regain balance after external disturbances or shifts in the support surface in dynamic conditions (Arifin et al., 2014). Postural control is a complex task that necessitates the integration of visual, vestibular, and somatosensory inputs from across the body to assess body position and movement in space, as well as the ability to generate forces to control body position (Doshi & Akulwar-Tajane, 2021). A high capacity for maintaining postural balance, which involves keeping the vertical projection of the center of gravity within the base of support, is crucial in sports (Andreeva et al., 2021). In the postural control system, the central nervous system (CNS) manages sensory information from the visual, vestibular, and somatosensory systems to generate sufficient motor output to sustain a controlled body posture (Opala-Berdzik et al., 2021). In static conditions, balance performance is linked to minimizing body sway while maintaining standard body postures (Paillard, 2019). One of the most vital motor coordination skills is the ability to maintain balance, which is essential due to its significant impact on sustaining a vertical body posture (Jaworski et al., 2023). Balance abilities and their effectiveness vary significantly based on age, gender, type of balance intervention, and type of sport (Kenville et al., 2021), obesity (Carneiro et al., 2012), total body fat percentage (Delfa-De la Morena et al., 2021), and forward head posture (FHP) as one of the most common postural deviations in the sagittal plane (Lin et al., 2022).

Several clinical studies have found that various types of physical activities involving slow movements and allowing individuals to self-monitor these movements are likely to have a positive effect on body balance control (Yasuda et al., 2012). Additionally, postural stability can be significantly affected by exposure to stressful conditions, such as working at heights (Cyma et al., 2018). There is a significant to strong negative correlation between BMI and postural balance, particularly for static balance with eyes open and closed (Díaz Escobar et al., 2021) and using sway on hard and foam surfaces in overweight and obese groups (Almurdi, 2024). Clinically, this indicates that young adults with obesity exhibit poor postural stability. These findings also suggest that postural instability in individuals with obesity is related to increased lordosis due to abdominal fat and poor integration of plantar somatosensory input (Nak, 2016). Understanding the control of postural stability, which is crucial for daily activities and sports success, remains challenging due to unclear terminology and the numerous outcome measures (Pickerill & Harter, 2011).

Postural skills can be measured to evaluate postural performance not only by assessing the movement of the Center of Mass (COM) and Center of Pressure (COP), (Paillard, 2019). This allows for postural stability measurements using other approaches, such as in this study, by observing body movement and measuring the angle of body tilt that occurs during the test. According to (Zemková, 2022), there is still a gap in the literature and investigation of postural sway responses to physical exercise. In this study, we limited postural stability to measuring the body's ability to maintain a stable static position with minimal movement against the force of gravity, represented by the sagittal and frontal axes of the body. This study involved students of the English Education Program who attended a General Physical Education course for one semester (16 sessions), with each session lasting 2x50 minutes and conducted once a week. Each session included different physical education materials aimed at providing basic knowledge and physical education competencies to prospective English Education teachers, as well as offering physical education experiences to enhance their activity levels, fitness, and physical condition. This also included various movement experiences to improve their basic motor skills, using valid sensors to measure body movement during stability tasks (Lariviere, 2013; Yudho FHP, 2024). The study aims to determine the effect of a physical education curriculum-based intervention on postural stability in female students who are not majoring in physical education.

Method

Participants

The research sample consisted of 35 female students, with an x̄ age of 18.9 years (SD ± .832) and x̄ BMI of 20.9 (SD ± 4.36). This study focused on assessing postural stability through a series of standing scenarios: bipedal (Bi), unipedal (Uni), and tiptoe (Tip), each lasting 10 seconds per test. These tests, developed by (Yudho, Hasanuddin, et al., 2024), utilized an inclinometer sensor to accurately measure balance and stability in each posture. These scenarios were designed to challenge various aspects of postural control, providing a comprehensive evaluation of the participants' ability to maintain stability under different conditions. The stability measurements demonstrated by the participants refer to a tool that has been statistically validated for its reliability and accuracy (Yudho, Fachrezzy, et al., 2024). The benchmark figures in this study represent the tilt angles of the sample's movements during the tests.

Table 1. Descriptive Anthropometry

	Age	Weight	Height	BMI
N	35	35	35	35
Mean	18.9	50	155	20.9
SD	.832	9.5	4.96	4.36
Min	18	35	144	15.2
Max	21	80	165	34.2

Procedure

In this test, the measured angle of inclination variables is the X-axis, which represents the body's sagittal plane, and the Y-axis, which represents the frontal plane. The data analysis compares the SD and the Mean of the inclinometer sensor measurements before and after the implementation of the physical education-based intervention. An SD and Mean close to 0 are considered indicative of good stability.

Table 2. Physical Education Intervention

No.	Study Materials	Learning Activities	Time
1	Introduction	1. Course contract and Theory of Physical Education 2. Pre-Test	2x50 minutes
2	Physical Fitness Training I	1. Strength and Conditioning 2. 600m Endurance run	2x50 minutes
3	Physical Fitness Training II	1. Balance and body stretch 2. 100m dash	2x50 minutes
4	Sprint and Relay Running	1. Crouch Start, Standing Start, Flying Start 2. Short Distance Running 3. 4x100m Relay Running	2x50 minutes
5	Volleyball	1. Under and Overhead Pass 2. Volleyball Service 3. Spike 4. Simple Volleyball Game	2x50 minutes
6	Basketball	1. Passing 2. Dribbling 3. Shooting 4. Lay-up 5. Simple Basketball Game	2x50 minutes
7	Handball	1. Passing 2. Dribbling 3. Shooting 4. Simple Handball Game	2x50 minutes
8	Knowledge and Practice Test	Middle Exam	2x50 minutes
9	Soccer	1. Passing 2. Dribbling 3. Shooting 4. Simple Soccer Game	2x50 minutes
10	Futsal	1. Passing 2. Dribbling 3. Shooting 4. Simple Futsal Game	2x50 minutes
11	Baseball	1. Throwing and catching 2. Hitting the Ball 3. Simple Baseball Game	2x50 minutes
12	Hadang (Indonesian Traditional Guardian Game)	1. Hadang (Guardian) Game Patterns 2. Simple Hadang Game	2x50 minutes

13	Dodgeball	1. Throwing the Ball 2. Dodgeball Game Patterns 3. Simple Dodgeball Game	2x50 minutes
14	Kasti (Indonesian Traditional Baseball Game)	1. Throwing and catching 2. Hitting the Ball 3. Simple Kasti / Traditional Baseball Game	2x50 minutes
15	Swimming	1. Water Games 2. Treading water 3. Freestyle Swimming 4. Breaststroke	2x50 minutes
16	Knowledge and Practice Test	Final Exam and Post-test	2x50 minutes

Data collection and analysis / Statistical analysis

Data collection was conducted twice: during the pre-test session at the beginning of the semester and the post-test session at the end of the semester, with a research duration of 16 weeks. The data was analysed using descriptive and inferential analysis with the software JAMOVI 2.5.6 (Navarro & Foxcroft, 2022; JAMOVI, 2024) to test the significance and effect of the intervention on the postural stability ability of the samples. Jamovi was selected for statistical analysis due to its user-friendly interface, efficiency, and reliability. Its structured workflow allowed for precise data processing and analysis while maintaining transparency and reproducibility. The software's built-in statistical tools provided accurate results without requiring extensive technical expertise, making it an effective choice for this research. Additionally, it facilitated clear data visualization, enhancing the interpretation of findings. Its open-source nature ensured flexibility and accessibility, making it a suitable platform for conducting the required analyses efficiently.

Results

To present the study's findings and examine the relationship between physical activity and postural stability, statistical analysis was conducted to assess key variables and their interactions. Descriptive statistics provide an overview of the sample characteristics, while inferential tests evaluate the significance of observed differences and associations. The following table summarizes the descriptive statistics for the primary variables under investigation.

Table 3. Descriptive Data

Pre-Test	SD-Bi-X	SD-Bi-Y	SD-Uni-X	SD-Uni-Y	SD-Tip-X	SD-Tip-Y	M-Bi-X	M-Bi-Y	M-Uni-X	M-Uni-Y	M-Tip-X	M-Tip-Y
N	35	35	35	35	35	35	35	35	35	35	35	35
Mean	.82	.159	.801	.392	2.25	1.98	1.09	.227	.823	.447	2.03	1.65
Median	.805	.153	.802	.422	2.11	2.09	1.05	.221	.808	.464	1.82	1.59
SD	.387	.0833	.24	.127	1.83	1.39	.635	.101	.304	.197	1.85	1.34
Min	.158	.0343	.338	.146	.5	.29	.338	.045	.233	.045	.37	.188
Max	1.74	.379	1.57	.647	11.1	5.79	3.52	.582	1.64	1.02	1.2	6.53
Skewness	.789	1.04	1.42	.045	3.53	1.45	2.18	1.31	.818	.475	3.36	1.79
SW - W	.935	.908	.855	.958	.655	.844	.795	.909	.927	.971	.592	.834
SW - p	.038	.007	<.001	.205	<.001	<.001	<.001	.007	.023	.47	<.001	<.001
Post-Test	SD-Bi-X Post	SD-Bi-Y Post	SD-Uni-X Post	SD-Uni-Y Post	SD-Tip-X Post	SD-Tip-Y Post	M-Bi-X Post	M-Bi-Y Post	M-Uni-X Post	M-Uni-Y Post	M-Tip-X Post	M-Tip-Y Post
N	35	35	35	35	35	35	35	35	35	35	35	35
Mean	-.57	-.0348	-1.12	-.026	-.314	.437	-1.37	-.1	-.844	.0444	-.776	-1.04
Median	-.591	-.0417	-.986	-.0757	-.448	.651	-1.07	-.046	-.831	-.0383	-.726	-.857
SD	1.33	.305	1.58	.773	3.57	2.23	1.75	.424	1.27	.702	3.61	1.61
Min	-4.81	-1.01	-6.17	-2.22	-7.3	-3.66	-7.42	-1.12	-3.03	-2.05	-12.4	-4.77
Max	2.54	.683	1.49	1.74	12.9	6.18	1.3	.794	2.6	1.19	9.22	2.1
Skewness	-.919	-.743	-1.3	-.24	1.62	.128	-1.37	-.308	.473	-1.22	-.471	-.502
SW - W	.919	.934	.885	.945	.826	.955	.898	.982	.952	.878	.919	.941
SW - p	.014	.037	.002	.082	<.001	.163	.004	.826	.132	.001	.013	.062

As seen in the two datasets provided above, showing the pre-test and post-test results for several variables across the categories of SD-Bi (bipedal), SD-Uni (unipedal), and SD-Tip (tiptoe), each with a sample size of 35. During the pre-test, the average values of variables in each category varied. For example, the mean for SD-Bi-X was .82 with a SD of .387, whereas SD-Bi-Y had a lower mean of .159 and an SD of .0833. The SD-Uni category showed a similar pattern, with SD-Uni-X having a mean of .801 and a SD of .24, while SD-Uni-Y had a mean of .392 and a SD of .127. The SD-Tip category had the highest average values in the pre-test, with SD-Tip-X averaging 2.25 and an SD of 1.83, and SD-Tip-Y averaging 1.98 with a SD of 1.39. In the post-test, there was a significant decline in the mean for many variables. The mean for SD-Bi-X dropped to -.57, with an increased SD of 1.33, and SD-Bi-Y changed to -.0348 with an SD of .305. The variable SD-Uni-X experienced a decline in the mean to -1.12 with an SD of 1.58, and SD-Uni-Y dropped to -.026 with an SD of .773. For the SD-Tip category, the mean for SD-Tip-X changed to -.314 with a SD of 3.57, while SD-Tip-Y showed an increase in mean to .437 with a SD of 2.23. The minimum and maximum values also indicated a wider range in the post-test, as seen in SD-Bi-X, which ranged from -4.81 to 2.54, and SD-Tip-X, which ranged from -7.3 to 12.9. The comparison between pre-test and post-test shows that the means decreased, and the variation increased for most variables, which may indicate more stable conditions. The increased SD in the post-test suggests greater variability in the results, implying more significant fluctuations after the intervention or other testing factors. Overall, this analysis shows significant changes in performance and consistency between the pre-test and post-test results. We used the Friedman test to compare postural stability under different conditions—before, during, and after physical activity—due to a violation of the normality assumption, as seen in the table below.

Table 4. Repeated Measure ANOVA SD and M between 6 component tests

Friedman	χ^2	df	p
SD Pre-test	132	5	< .001
M Pre-Test	31.2	5	< .001
SD Post-test	123	5	< .001
M Post-Test	41.1	5	< .001

The results of the Friedman statistical test indicate that there are significant differences in various measurements before and after the intervention. This test is used to determine differences significancy between several related groups. For the pre-test measurements in the SD category, the Friedman statistic (χ^2) is 132 with 5 degrees of freedom (df) and a p-value of < .001, showing that the differences between these groups are statistically significant. This means there is a consistent change in the SD measurements before the intervention. Similarly, in the M pre-test category, the (χ^2) value is 31.2 with 5 df and a p-value of < .001, also showing significant differences between these groups. The post-test measurements show a similar pattern. For the SD post-test category, the (χ^2) value is 123 with 5 df and a p-value of < .001, indicating that the differences between groups in the SD measurements after the intervention remain significant. In the M post-test category, the (χ^2) value is 41.1 with 5 df and a p-value of < .001, showing significant differences between the M groups after the intervention. These results suggest that the intervention administered has a significant impact on the measurement outcomes in both the SD and M categories, both before and after the intervention, with the changes being consistent across all groups tested.

Table 5. Paired Samples T-Test

Test Variables		Stats Test	Statistic	p	Mean difference	SE difference	Effect Size
SD-Bi-X	SD-Bi-X Post	Wilcoxon W	602	< .001	1.211	.2454	.911
SD-Bi-Y	SD-Bi-Y Post	Wilcoxon W	519	< .001	.172	.0554	.648
SD-Uni-X	SD-Uni-X Post	Wilcoxon W	617	< .001	1.788	.2742	.959
SD-Uni-Y	SD-Uni-Y Post	Wilcoxon W	516	< .001	.42	.1298	.638
SD-Tip-X	SD-Tip-X Post	Wilcoxon W	585	< .001	2.601	.4336	.857
SD-Tip-Y	SD-Tip-Y Post	Wilcoxon W	515	< .001	1.377	.4046	.635
M-Bi-X	M-Bi-X Post	Wilcoxon W	626	< .001	2.125	.3283	.987
M-Bi-Y	M-Bi-Y Post	Wilcoxon W	549	< .001	.296	.0739	.743
M-Uni-X	M-Uni-X Post	Wilcoxon W	610	< .001	1.65	.2216	.937
M-Uni-Y	M-Uni-Y Post	Wilcoxon W	507	< .001	.356	.118	.61
M-Tip-X	M-Tip-X Post	Wilcoxon W	579	< .001	2.313	.7084	.838
M-Tip-Y	M-Tip-Y Post	Wilcoxon W	613	< .001	2.553	.3789	.946

Note. H_a μ Measure 1 - Measure 2 > 0

The results of the Wilcoxon test, conducted to assess changes in postural sway stability between the pre-test and post-test across multiple variables, indicate significant improvements in both the sagittal (X) and frontal (Y) planes. For the variable SD-Bi-X, representing postural sway stability in the sagittal plane under bilateral stance, the Wilcoxon test yielded a W statistic of 602 with a p-value of $< .001$, highlighting a statistically significant improvement. The mean difference of 1.211 (SE = .2454) and an effect size of .911 indicate a substantial and meaningful enhancement in stability. In contrast, for SD-Bi-Y, reflecting sway stability in the frontal plane under bilateral stance, the W statistic of 519 and a p-value of $< .001$ also show a significant improvement, albeit with a smaller mean difference of .172 (SE = .0554) and an effect size of .648, indicating a more moderate change. For SD-Uni-X, representing sway stability in the sagittal plane during unilateral stance, the W statistic of 617 and a p-value of $< .001$ reveal a highly significant improvement. The mean difference of 1.788 (SE = .2742) and a very large effect size of .959 suggest considerable gains in stability following the intervention. SD-Uni-Y, which reflects sway stability in the frontal plane during unilateral stance, shows a W statistic of 516 ($p < .001$), with a mean difference of .42 (SE = .1298) and an effect size of .638. While significant, this change is relatively smaller compared to SD-Uni-X. SD-Tip-X, indicating sway stability in the sagittal plane during tiptoe stance, shows the most pronounced improvement, with a W statistic of 585 and a p-value of $< .001$. The mean difference of 2.601 (SE = .4336) and an effect size of .857 highlight a substantial impact of the intervention on sagittal plane stability. Lastly, SD-Tip-Y, reflecting stability in the frontal plane during tiptoe stance, has a W statistic of 515 ($p < .001$), with a mean difference of 1.377 (SE = .4046) and an effect size of .635, demonstrating significant improvement but with a more moderate effect compared to other variables.

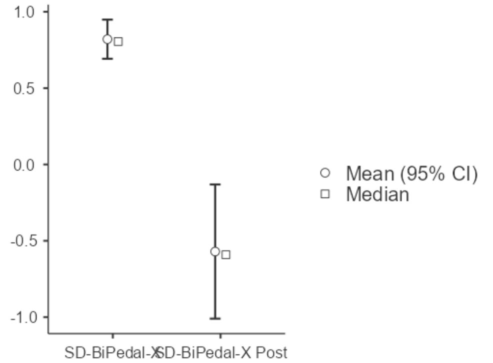
The test results also indicate significant changes in postural tendencies before and after the intervention, both in the X angle (sagittal plane) and the Y angle (frontal plane). For the M-Bi-X and M-Bi-X Post pair, W=626W = 626, p<0.001p < 0.001, with a mean difference of 2.125 and a standard error (SE) of 0.3283, indicating significant improvement in postural tendencies in the sagittal plane, with a correlation of 0.987. For the M-Bi-Y and M-Bi-Y Post pair, W=549W = 549, p<0.001p < 0.001, with a mean difference of 0.296, SE of 0.0739, and a correlation of 0.743, showing a small but significant improvement in the frontal plane. The M-Uni-X and M-Uni-X Post pair shows W=610W = 610, p<0.001p < 0.001, with a mean difference of 1.65, SE of 0.2216, and a correlation of 0.937, reflecting improvement in the sagittal plane. For the M-Uni-Y and M-Uni-Y Post pair, W=507W = 507, p<0.001p < 0.001, with a mean difference of 0.356, SE of 0.118, and a correlation of 0.61, showing a small but significant improvement in the frontal plane. The M-Tip-X and M-Tip-X Post pair resulted in W=579W = 579, p<0.001p < 0.001, with a mean difference of 2.313, SE of 0.7084, and a correlation of 0.838, indicating a significant improvement in the sagittal plane. Finally, for the M-Tip-Y and M-Tip-Y Post pair, W=613W = 613, p<0.001p < 0.001, with a mean difference of 2.553, SE of 0.3789, and a correlation of 0.946, reflecting a significant improvement in the frontal plane. Overall, these findings demonstrate that the intervention had a substantial impact on postural tendencies, with the most significant changes observed in the sagittal plane (M-Tip-X) and the frontal plane (M-Tip-Y).

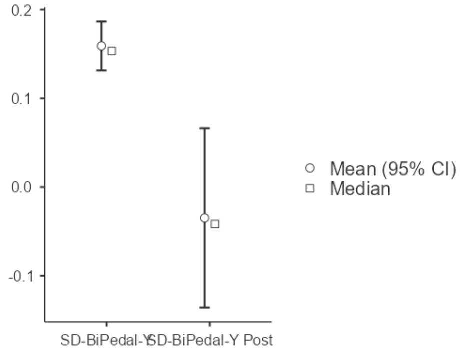
Overall, the Wilcoxon test results indicate significant and meaningful differences between the pre-test and post-test outcomes across all variables tested, with varying effect sizes. All findings suggest a positive impact from the intervention. The alternative hypothesis is accepted, confirming that post-test values are lower compared to pre-test values in every case, indicating a reduction in body tilt and an improvement in postural stability, as reflected by a decrease in body sway among the participants. The changes are more pronounced in the sagittal plane (X-axis) than in the frontal plane (Y-axis), particularly under unilateral and tiptoe stance conditions.

Fig 1-12. Graphs of paired sample T-test

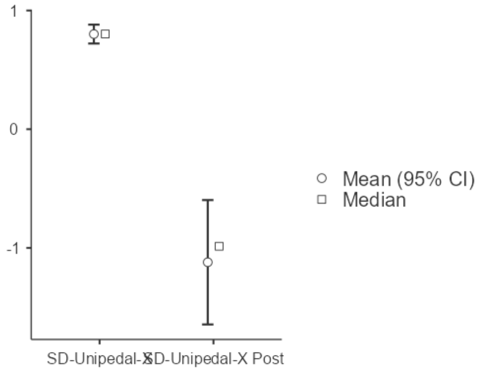
SD-Bi-X - SD-Bi-X Post

SD-Bi-Y - SD-Bi-Y Post

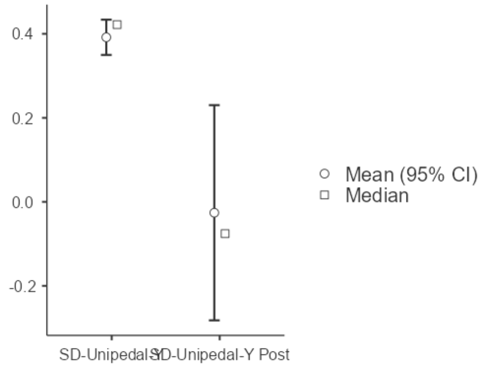




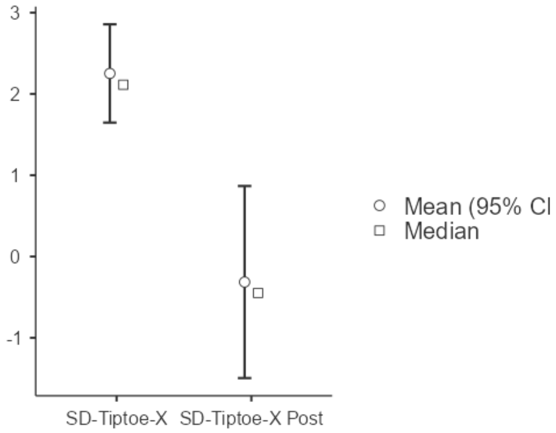
SD-Uni-X - SD-Uni-X Post



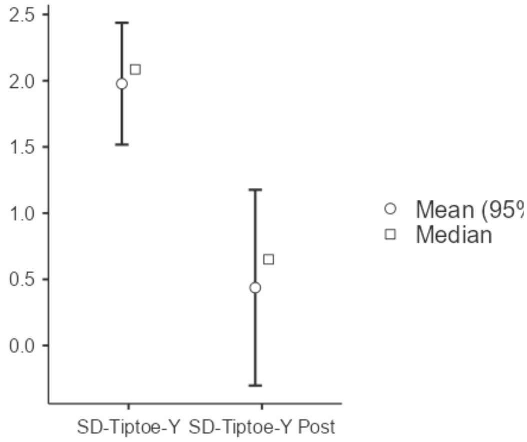
SD-Uni-Y - SD-Uni-Y Post



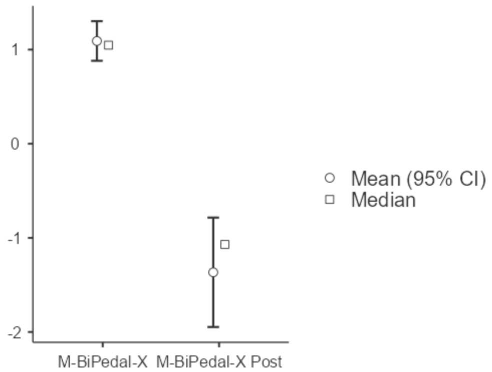
SD-Tip-X - SD-Tip-X Post



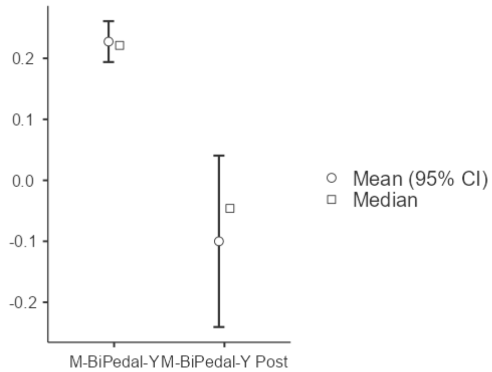
SD-Tip-Y - SD-Tip-Y Post

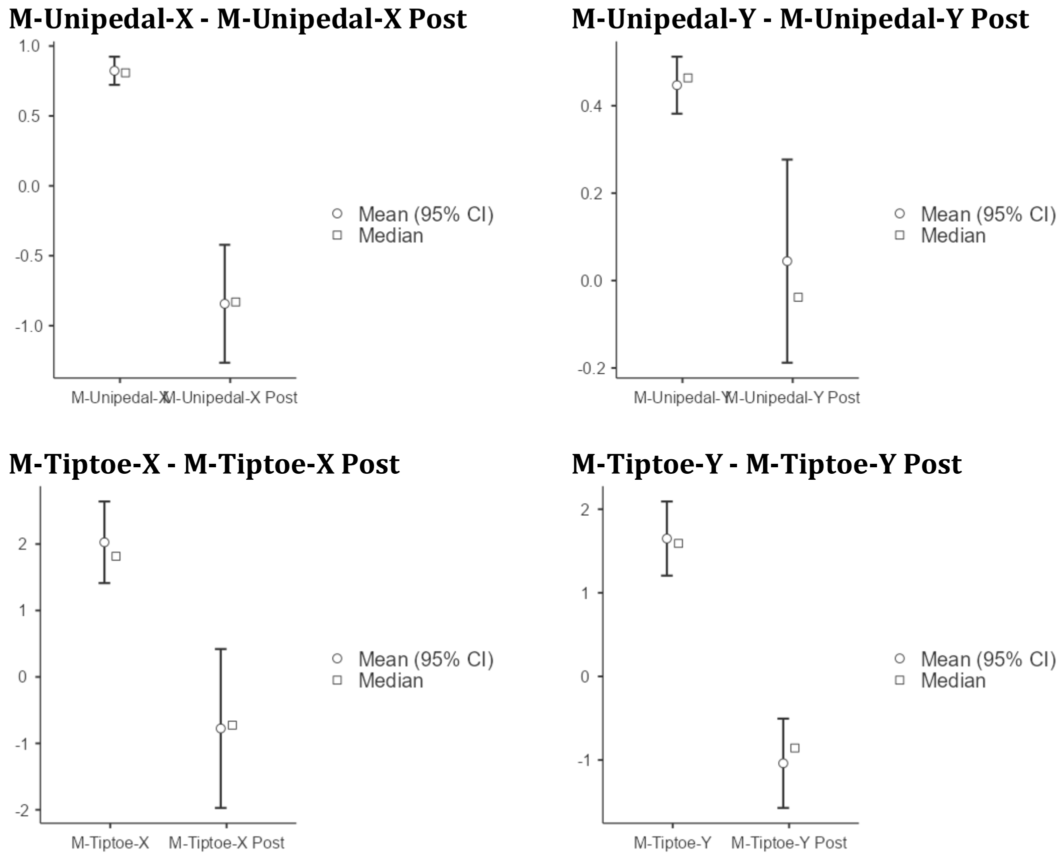


M-BiPedal-X - M-BiPedal-X Post



M-BiPedal-Y - M-BiPedal-Y Post





Discussion

The comparison between pre-test and post-test shows that the means decreased, and the variation increased for most variables, which may indicate a more stable performance or posture changes in testing conditions. The increased SD in the post-test suggests greater variability in the results, indicating more significant fluctuations after the intervention or other testing factors. Overall, this analysis shows significant changes in performance and consistency between the pre-test and post-test results. The results of the Friedman statistical test indicate that there are significant differences in various measurements before and after the intervention. This test is used to determine differences significancy between several related groups. These findings suggest that the intervention administered has a significant impact on the measurement outcomes in both the SD and M categories, both before and after the intervention, with the changes being consistent across all groups tested. The Wilcoxon test results conducted to examine the hypothesis of change between pre-test and post-test across several variables, indicate significant and meaningful differences between the pre-test and post-test results for all variables tested, with varying effect sizes, but all showing a positive impact from the intervention.

The alternative hypothesis is accepted, confirming that post-test values are lower compared to pre-test values in each case. Overall, the mean and standard deviation measurements on both the X and Y axes indicate that participants exhibited enhanced postural stability control following the completion of a 16-session physical activity program integrated into the Physical Education curriculum. These findings support previous research suggesting that proficiency in sports enhances standing stability (Omorczyk et al., 2018) and cognitive flexibility in dual-task situations (Chen et al., 2024). Controlling postural stability in the anterior-posterior direction is more challenging than in the medio-lateral plane (Olchowik et al., 2020). Furthermore, these findings reinforce previously uncovered facts regarding the importance of postural stability within the scope of physical activities, sports, and overall biomotor abilities, where engaging in various sports activities has been shown to improve postural stability (Andreeva et al., 2021), as do practices like Pilates (Li et al., 2024), Zumba (Ben Waer et al., 2024), and Tai Chi (Law & Li, 2023). Older adults who were physically active in their youth tend to have better body stability (Lamoth & van Heuvelen, 2012). Postural stability training is also essential as a physical intervention to enhance technical skills in various sports, such as badminton (Jaworski et al., 2023), and to facilitate the early development of balance ability (Kenville et al., 2021). This can be achieved through various foot placement and visual conditions (Jaworski et al., 2023), self-monitoring exercises (Yasuda et al., 2012), proprioceptive training using unstable devices (Rizzato et al., 2021), 6-month-long of special programme of exercises (ComplexCore™) (Hianik et al., 2017), 8 weeks of proprioceptive training (Grueva-Pancheva, 2021), and ankle tape (Azhar et al., 2023) to improve particularly ankle stability, even to wear specialized clothing materials is useful to support postural stability (Cian et al., 2015). Additionally, postural re-education exercises are necessary for athletes involved in one-sided sports (Wilczyński et al., 2022).

Conclusions

The study's findings demonstrate a significant improvement in the body tilt and postural stability of the participants, particularly in the sagittal plane (X-axis). Initially, their posture tended to lean forward, but after completing 16 sessions of the physical education intervention program, their posture became notably more stable and upright, as reflected by the average negative values in the sagittal angle. Additionally, in the frontal plane (Y-axis), the participants showed improved stability following the intervention. These results indicate that the physical activity intervention had a substantial positive impact on enhancing the participants' postural stability.

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Authors' and translators' details:

Firdaus Hendry Prabowo Yudho	firdaushendryprabowoyudho_9904921035@mhs.unj.ac.id	Author
Fahmy Fachrezzy	fahmyfachrezzy@unj.ac.id	Author
Firmansyah Dlis	firmansyahdlis@unj.ac.id	Author
Firdaus Hendry Prabowo Yudho	firdaushendry85@gmail.com	Translator