THE ASEAN JOURNAL OF MILITARY AND PREVENTIVE MEDICINE

ISSN (e): 3031-870X
Vol. 3 No.2 (2026)
https://journal.ajmpm.net/

DOI: https://doi.org/10.47353/10.47353/ajmpm.v3i2.74

Dynamic balance standard values of combat soldiers readiness

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Abstract

Background: The Medical Rehabilitation Unit at Gatot Soebroto Army Central Hospital (RSPAD-GS) provides post-injury rehabilitation for soldiers and personnel at high risk of lower limb injuries. Reliable reference values are needed for injury prevention and rehabilitation assessment. The Star Excursion Balance Test (SEBT) was selected because it is simple and can be performed independently. This study also aimed to establish reference values for the iMoove dynamic balance device available at RSPAD-GS.
Methods: A cross-sectional comparative study included 30 male soldiers aged 20 to early 30s: 15 healthy soldiers (NS) and 15 soldiers with lower limb injuries (IS). All participants underwent SEBT and iMoove assessments.
Results: The healthy limb in the IS group showed significantly lower SEBT scores than the NS group in 5 of 8 directions ($p < 0.05$). The injured limb also scored significantly lower than the healthy limb in 5 of 8 directions ($p < 0.05$). Reference SEBT values for the NS group were 94.40% (anterior), 98.13% (anteromedial), 97.00% (medial), 99.00% (posteromedial), 94.67% (posterior), 97.86% (posterolateral), 86.53% (lateral), and 86.40% (anterolateral). The iMoove test showed a significant between-group difference in Phase III, with a reference value above 8.2 ($p = 0.007$).
Conclusion: Healthy soldiers had better dynamic balance than injured soldiers, including on the uninjured limb. These reference values can support injury prevention and rehabilitation in adults aged 20 to early 30s. An iMoove Phase III score above 8.2 may indicate normal dynamic balance.

Keywords: *Star Excursion Balance Test (SEBT), iMoove, reference values, preventive to medical rehabilitation, return to duty*.

Background

The life of a soldier is fraught with the risk of injury; when an injury occurs, there is great hope for recovery so that the soldier can return to duty—and even return to combat. This rehabilitation is carried out by the Medical Rehabilitation Unit at the Gatot Soebroto Army Central Hospital (RSPAD-GS), as part of the organization’s core mission to provide the best possible care to soldiers.

Postural control and neuromuscular balance are key bodily functions that play a role in maintaining stability while sitting, standing, walking, running, and encompassing all activities—both static and dynamic—in daily life. Balance assessments are frequently and critically important for clinicians to perform. These evaluations provide initial and follow-up data that are essential for evaluating therapeutic progress. Such balance assessments can be conducted using advanced tools like robots or through simpler methods without the need for sophisticated equipment.
Clinicians often use postural control assessments to evaluate the risk of injury, identify signs of injury-related deficits, or assess progress following therapy or intervention in injured patients1. Ernandini 2022 states that nearly 50% of military personnel with injuries involve (anterior cruciate ligament) ACL or (posterior cruciate ligament) ISL ruptures accompanied by meniscal tears. Ankle injuries are also common. These injuries significantly impair dynamic postural balance. This deterioration can result from pain, reduced muscle strength, and ligament weakness[2,3].

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The integrated neuromuscular system, comprising all sensory, motor, and central nervous systems, forms a system that builds and maintains joint function throughout static and dynamic movements—known as the proprioceptive system. Additionally, all ligaments help stabilize the joint. Therefore, injuries to the ACL or ISL not only result in pain but also disrupt the proprioceptive system[4, 5, 6].

The evaluation of this study utilized the Star Excursion Balance Test (SEBT) as a manual intervention because this test has shown intra-rater and inter-rater reliability coefficients ranging from 0.67 to 0.871. Based on these results, the test is considered to have moderate to high reliability for administration by other individuals in different settings using appropriate procedures.

IMoove is one of the diagnostic and balance training tools owned by RSPAD; unfortunately, the IMoove device does not yet have established reference values. This study is a pilot study with novel findings that can be used and utilized to establish reference values for soldier performance. These reference values can also be used by all RSPAD-GS members and the general public for the prevention of fall and injury risks and for recovery after injury.

Methods

The design of this study is a cross-sectional comparison, conducted at the Medical Rehabilitation Unit, RSPAD-GS, Jakarta. The research began with the preparation of a proposal, identifying subjects from whom to collect data, and analyzing the data from February 2023 to March 2023. Samples were collected consecutively from normal soldiers and soldiers recovering from injuries who met the admission criteria at RSPAD-GS in Jakarta. According to statistical principles, the minimum number of participants required is 30 respondents[7], based on equivalent age groups. Eligible participants were active-duty male combat soldiers aged 20 to early 30 years. Participants were assigned to either the healthy soldier (NS) group or the injured soldier (IS) group. The NS group consisted of soldiers without a history of lower limb injury, whereas the IS group included soldiers who had recovered from a unilateral lower limb injury and had completed medical rehabilitation. All participants met the physical requirements for military service and provided written informed consent before participation. Soldiers were excluded if they had chronic metabolic diseases, neurological disorders affecting balance, severe visual impairment, or vestibular symptoms such as recurrent vertigo or frequent sensations of falling. The analysis will utilize SPSS methods across several stages. The first stage involves assessing the characteristics of the study participants. The second stage involves determining the cutoff score for the SEBT to serve as a reference value. Third stage involves determining the cutoff score for the iMoove evaluation. Patient data will be stored confidentially on the researcher's computer.

Materials and Equipment

The study was conducted using an informed consent form and a standardized research data collection form. Anthropometric measurements included body weight, height, and lower limb length, which were measured using a digital weighing scale, height measuring device, and tape measure, respectively. Physiological parameters, including blood pressure, pulse rate, and oxygen saturation, were assessed using a sphygmomanometer, stethoscope, and pulse oximeter. Dynamic balance was evaluated using the Star Excursion Balance Test (SEBT) and the iMoove dynamic balance assessment system.

Study Workflow

All eligible participants who met the inclusion criteria and provided written informed consent underwent baseline assessments, including measurements of body weight, height, blood pressure, pulse rate, oxygen saturation, and lower limb length. Participants were subsequently assigned to either the healthy soldier (NS) group or the post-injury soldier (IS) group. Dynamic balance was then assessed using the SEBT and the iMoove system. The collected data were recorded and analyzed statistically.

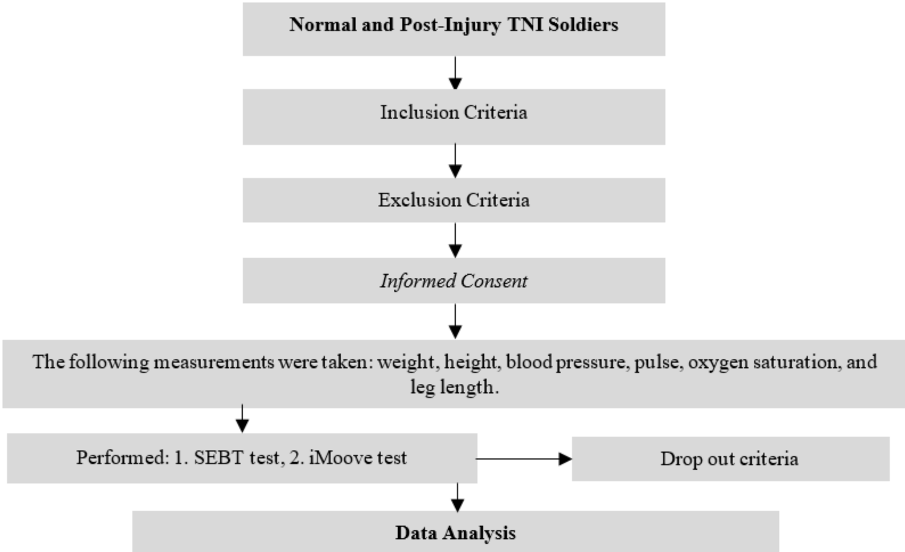

Figure 1. Study workflow.

Star Excursion Balance Test (SEBT)

Dynamic balance was assessed using the Star Excursion Balance Test (SEBT), which requires participants to maintain a single-leg stance while reaching maximally in eight directions with the contralateral limb. Participants were instructed to lightly touch the farthest possible point in each direction with the reaching foot before returning to the starting position without losing balance. The reach distance was measured from the center of the grid to the point of contact.

Each direction was performed three times for both the right and left lower limbs. The mean reach distance from the three trials was calculated and normalized to leg length using the following formula:

Normalized reach distance (%) = (Mean reach distance / Leg length) × 100

A trial was repeated if the participant failed to maintain balance, moved the supporting foot from the center position, failed to touch the designated line, could not return to the starting position, or used the reaching limb to provide substantial body support during the test.[8,9]

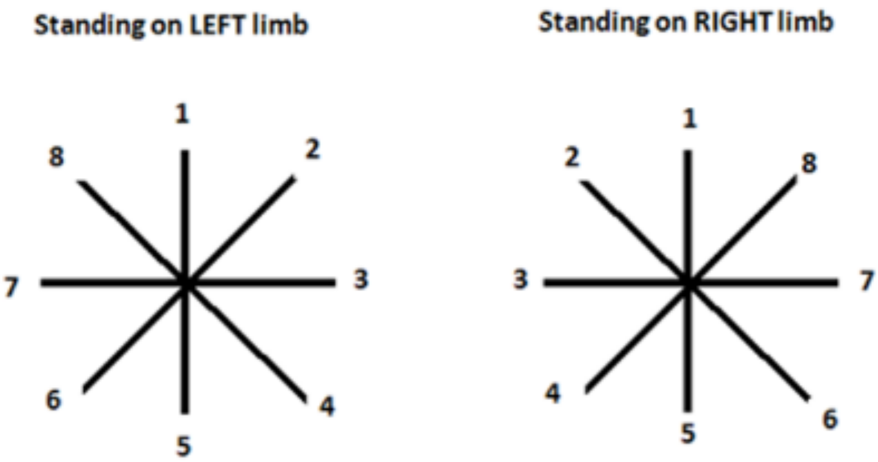

Figure 2. Star Excursion Balance Test (SEBT) directional reach layout.

iMoove Dynamic Balance Assessment

Dynamic balance was further evaluated using the iMoove system. Participants stood on the platform with both feet positioned parallel while maintaining an upright posture. The assessment began at Level I. Participants who achieved a score greater than 8.0 progressed sequentially to Levels II and III. The score obtained at each level was automatically recorded by the device and used for statistical analysis.

Figure 3. iMoove dynamic balance assessment system.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics version 28.0 (IBM Corp., Armonk, NY, USA). Continuous variables were summarized as means and standard deviations. Comparative analyses between groups were performed using appropriate statistical tests based on data distribution, with a p-value of <0.05 considered statistically significant.

Ethical Approval

This study was approved by the Ethics Committee of Gatot Soebroto Army Central Hospital (RSPAD-GS). All participants provided written informed consent before enrollment. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki. No external funding or conflicts of interest were declared.

Results

Data collection for this study took place from early March 2023 through March 13, 2023. The characteristics of the subjects were mentioned in **Table 1.** The subjects of the IS study were active and normal soldiers, with a history of injury including ACL reconstruction in 4 soldiers (26.67%), ACL and meniscus reconstruction in 6 soldiers (40%), a fall from a height resulting in a herniated disc at L5-S1 in 2 soldiers (13.3%), and ACL, ISL, and meniscus reconstruction in 1 soldier (6.67%), meniscus repair in 1 soldier (6.67%), and MCL reconstruction in 1 soldier (6.67%). On average, IS patients were referred to the Medical Rehabilitation Unit four weeks after surgery at RSPAD-GS. The NS study subjects were active-duty, normal soldiers from the NS referral list. Thus, it can be concluded that the units of origin for both NS and IS patients were from all over Indonesia.

Discussion

Research Implementation

This study utilized the SEBT and iMoove tests for the following reasons: the SEBT is a test that can be easily repeated by soldiers and the general public wherever they are; it is safe to perform; and it can serve both as a training exercise and as an evaluation or diagnostic test. The evaluation results can be immediately viewed and analyzed, even by the soldiers or patients themselves.

iMoove is a dynamic postural analysis tool integrated with software that allows for postural analysis during 3D movements. iMoove helps identify biomechanical abnormalities in the body. iMoove is a tool owned by

RSPAD-GS; therefore, this study required no additional budget and utilized the existing human resources and facilities at RSPAD-GS. Unfortunately, as of now, we have not obtained reference values for classification in the iMoove assessment. Consequently, the research team is attempting to establish these values.

Table 1. Characteristics of The Research Subjects

	Normal Soldier (NS) Mean ± SD / Median		Injured Soldier (IS) Mean±SD / Median		p	
Leg Length	86.00±2.6 86.5(81-89)		87.6±3.26 88.00(81-92.5)		0.12*	
Age	20.9±1.43		28.00±3.46		**0.014****	
BMI	21.98±1.20		24.04±2.66		**0.012****	
Duration after surgery (weeks)	-		16.93±8.91		-	
	Pre	Post	Pre	Post	Pre	Post
Systolic	131.86±9.53	128.00±9.10	132.06±6.80	136.60±8.64	0.21**	0.67**
Diastolic	87.26±11.68 88.00(63-108)	83.06±7.65 87.00(69-92)	93.33±10.36 95.00(77-107)	97.66±11.33 98.00(77-114)	0.89**	**0.03***
Heart rate	131.86±9.53	73.13±11.19	81.93±11.41	83.53±10.49	0.81**	0.71**
Oxygen Saturation	98.93±1.03 99.00(97-100)	99.00±0.84 99.00(97-100)	98.46±0.74 98.00(97-100)	97.86±2.66 99.00(89-100)	0.17*	0.12*

*Mann-Whitney Test
**Independent T-test

Table 2. SEBT Scores for Normal Soldiers and Injured Soldiers

Direction	NS (%) n=15	IS (%) n=15			p (NS with injured leg IS	p (healthy leg IS with injured leg IS)
		Healthy leg	p (NS with healthy leg IS	Injured leg		
Anterior	94.40±7.78 93(81-106)	69.86 ±15.75 73(19-82)	**0.001***	58.20±25.44 66.00(0-81)*	**0.001***	**0.009*****
Anteromedial	98.13 ± 8.07	72.20 ±17.73	0.12**	60.06±25.99 71.00(0-85)*	**0.001***	**0.025*****
Medial	99.80 ± 8.05	69.00 ±17.94	0.05*	57.9±25.83 69.00(0-83)*	**0.001***	**0.041*****
Posteromedial	99.00±7.37 99.00(85-117)	67.53±18.45 70.00(16-96)	**0.001***	57.20±25.72 63.00(0-85)*	**0.001***	0.088***
Posterior	94.67±6.89	66.13±19.5	**0.02***	55.60±25.09 65.00(0-81)*	**0.001***	0.099***
Posterolateral	97.86±8.58	62.67±20.04	**0.02****	57.20±25.72 63.00(0-85)*	**0.001***	0.307***
Lateral	86.53±9.46 87.00(66-105)	54.73±20.62	**0.001****	45.60±25.39	**0.001***	**0.036******
Anterolateral	86.40±6.91	65.53±16.94	0.13*	55.26±24.55 65.00(0-86)*	**0.001***	**0.017*****

*Mann-Whitney Test
**Independent T-test
***Wilcoxon Test
****Paired T-Test
NS: Normal soldiers IS: Injured soldiers

Table 3. iMoove Scores for Normal soldiers and Injured Soldiers

	Normal Soldiers		Injured Soldiers		p
	Mean±SD	Median	Mean±SD	Median	
Phase I	9.54±0.30	9.60(8.8-9)	9.17±0.52	9.40(7.7-9.9)	0.15*
Phase II	9.30±0.40	9.40(8.5-9.8)	8.40±2.53	9.40(0-9.9)	0.27*
Phase III	9.20±0.44	9.30(8.2-9.9)	5.32±4.52	8.20(0-9.8)	**0.007***

*Mann-Whitney Test

SEBT and iMove data collection was conducted indoors at a temperature of 22°C. According to Racinais (2017), the optimal temperature for exercise is around 22°C–24°C. The body can still tolerate moderate-to vigorous physical activity optimally for up to 15 minutes at ambient temperatures of up to 30°C[11].

According to a study by Fakhrazi (2022) on the three branches of the Indonesian National Armed Forces (TNI), the Army has a higher risk of knee pain compared to the other branches, with an incidence rate of 16.1 per 1,000 enlisted personnel and 7.7 per 1,000 officers per year. Ernandini (2022) cited 2018 data from a rehabilitation center, indicating that 75% of service members' disabilities stem from injuries in the lumbar region and below. 46% of the injuries that ultimately led to disability were ACL/ISL injuries that were not properly treated[2, 12, 13].

Characteristics of The Research Subject

The results of this study indicate that there are significant differences in age, BMI, and diastolic blood pressure. There was a significant difference in age, but both groups had an average age of 20 to early 30s. Jackson et al. (2009) observed a decline in cardiopulmonary fitness and muscle strength with increasing age; their study indicated that this decline becomes apparent every ten years and is estimated to begin in the group aged 40 and older[14]. Research results by Yanne Salviano Pereira (2014) indicate that age is closely related to balance. Considering the age of the study subjects and based on the above statement, it can be concluded that these two groups are still comparable[15].

Research by Thatiane Lopes Valentim and Paschoale Ostolin (2020) shows that obesity or a high BMI affects balance posture but does not indicate a link between obesity and the risk of falling. SEBT testing may yield better results when performed on individuals who are not obese. Individuals with obesity exhibit greater torsional forces and bear a higher gravitational load on the lower extremities compared to those with a normal BMI, resulting in lower SEBT scores than individuals with a normal BMI15. According to research by Delporto et al. (2012), a significant reduction in reach is more pronounced in the anterior direction in individuals with obesity. An individual with a normal BMI maximizes trunk flexion to avoid high torsion at the knee joint. An obese individual may be unable to perform trunk flexion due to restrictions in the abdominal region. This also prevents vertebral torsion, which can cause back pain due to limitations in trunk flexion movement[16, 17].

Analysis of SEBT Scores for Healthy Limbs in Injured Soldiers (IS) Compared to Normal Soldiers (NS)

The study found statistically significant differences in scores between the IS group and the NS group in the healthy leg across 5 of the 8 directions examined: anterior, posteromedial, posterior, posterolateral, and lateral. Based on a systematic review by Philip A (2012), 11 other journal articles were identified that reported results similar to those of this study. The anterior, posteromedial, and posterolateral directions are the most important for assessing knee instability and evaluating the risk of lower extremity injury. To perform daily activities under any conditions, maintaining balance and stability is crucial to prevent the risk of falls and slips[1].

A study conducted in India by Lilima Patel (2018) found that SEBT scores were higher for the right leg compared to the left leg, as more participants were right-leg dominant. This aligns with our study on NS, which found that the right leg scored higher than the left leg. Bahamonde R et al (2007) found that by using the dominant leg, a person can jump farther with that dominant leg; this result is attributed to the dominant leg having better vertical and horizontal ground reaction forces compared to the non-dominant leg[9,10]. The situation changes when a soldier is injured; they must designate whichever leg is uninjured as their dominant leg and bear more weight on that leg. This serves as the body's compensatory mechanism to protect the injured leg.

Paula Calori Domingues (2018) noted a relationship between flexor strength and anterior and posterior directions. In normal lower limb kinesiology, this highlights the importance of knee flexor strength for performing movements that place the leg in front of or behind the body's midline. These movements place approximately 60% more load on the knee flexor muscles than when standing upright[1]. Michael Lewek (2002) stated that following ACL reconstruction, there is a significant decrease in quadriceps muscle strength. In 10 patients post-reconstruction surgery, a reduction in quadriceps muscle strength of <80% was observed. This results in the inability of the knee to achieve maximum flexion due to muscle atrophy[18, 19].

Table 2 shows that, although the unaffected limb was uninjured, the IS group still had a lower SEBT score than the NS group. This demonstrates that when treating a patient, we must adopt a comprehensive and holistic approach. An injury to one limb significantly affects the individual as a whole, impacting daily activities—even light ones—and especially during strenuous activities. Education and exercise must still involve the uninjured side. Patients often require mobility aids such as canes, walkers, wheelchairs, or other orthotic devices. The use of these assistive devices is a necessity and not a form of dependency. From the statistical analysis of this study, it can be seen that the functional capacity of the healthy limb in IS is still below that of the healthy limb in NS. This means that these soldiers have a higher risk of falling or being reinjured compared to NS.

SEBT Scores in Injured Soldiers (IS)

SEBT scores in the injured leg of the IS group were significantly lower than those in the uninjured leg. Significant differences between the injured and healthy legs on the IS were primarily observed in the anterior ($p=0.009$), anteromedial ($p=0.025$), medial ($p=0.041$), lateral ($p=0.036$), and anterolateral ($p=0.017$) directions. The SEBT scores for the healthy leg also had a lower average compared to NS. Fundamentally, from a kinesiological perspective, the movements in this SEBT test reflect the global movements of daily life required to move the knee, involving the hip, spine, knee, and ankle. Examples include walking, going up and down stairs, bending over, and changing position from sitting to standing or vice versa.

Previous studies have reported that muscle strength deficits can be observed six to twelve months after ACL reconstruction surgery, particularly in the quadriceps and hamstrings. These changes in muscle strength occur due to decreased muscle activity, leading to muscle atrophy. The magnitude of these muscle deficits has been reported to be 6–10% lower than in the contralateral limb[18, 19]. Several other studies have reported neuromuscular control and postural control deficits in patients who underwent ACL/ISL reconstruction surgery. Post-surgery, a decrease in proprioception may occur, linked to the loss of mechanoreceptors. Another study found significant differences between the healthy limb and the injured limb when the knee was flexed to 45° up to 6 months post-surgery[20, 21].

Muscle atrophy leads to a decrease in the number of myofibrils, thereby reducing muscle capacity or endurance. Significantly reduced muscle endurance also results in a low tolerance for fatigue[22]. Fatigue alters the efficiency of contraction in extrafusal muscle fibers and challenges the efficiency of afferent information from the muscles, which ultimately alters neuromuscular control[1].

In IS, the healthy leg is often used for weight-bearing rather than the injured leg. During the gait cycle, the injured leg cannot be used for weight-bearing. The stance phase of the gait cycle is reduced to 40% of the total 60% stance phase of the gait cycle. The weight-bearing period for the injured leg becomes shorter. This situation causes the healthy leg to bear an excessive load because it must absorb the load transferred from the injured leg; this overloading is detrimental to the healthy leg[23]. It is this condition that causes a person to walk with a limp. While still limping, the patient should use a walking aid. This is often not followed by injured patients, as they feel embarrassed or fear becoming dependent. A limping gait in ACL/ISL and/or meniscus injuries is also frequently caused by the injured knee's inability to achieve full extension—a prerequisite for the heel strike position that initiates weight-bearing on the leg—while the other leg performs hamstring flexion to prevent tripping.

An interesting finding from this study is that the average SEBT score was higher among military personnel than among the general Indian population, based on average leg reach scores at the same height (160 cm – 170 cm, 170 cm – 180 cm). The average SEBT score for the anterior direction was 76.7 for the right leg and 88 for the left leg, whereas for the Indian control group, the average score for the right leg was 67.9 and for the left leg was 68.46.

iMoove Scores for Injured Soldiers and Normal Soldiers

iMoove is a device owned by the Medical Rehabilitation Department at RSPAD, capable of training and evaluating patients in three dimensions. iMoove operates using ellipsoidal movements. These movements indirectly engage all the muscles, joints, and ligaments in the body, from head to toe. These movements stimulate the proprioceptive system in the joints, as well as the musculoskeletal and neuromuscular systems. Through these movements and stimulation, the exercises strengthen the muscle and ligament systems, increasing their flexibility—as well as that of the joints—thereby leading to improved posture[24].

The integrated evaluation program, IMoove feedback software, is designed for postural and proprioceptive analysis in three-dimensional movement. Postural stability is the ability of body segments to actively resist external forces, thereby maintaining a stable position. The concept of stability is closely related to posture. In the locomotor system, postural stability occurs when the body's joint structures (center of pressure, COP) do not bear excessive pressure on one side, and muscles work in good coordination, preventing the body from falling. Maintaining or resisting the force of gravity is a primary motor skill that helps keep the body upright. This mechanism is regulated by motor programs that coordinate muscle movements[24]. Through 3-dimensional movement, iMoove can activate multiple muscles simultaneously. The motor plate on iMoove moves in three dimensions, stimulating the body across three planes via centrifugal force. This force trains the body in natural, spiral-like movements. iMoove can provide benefits such as increased strength and improved movement in simple postures.

The values shown in the analysis results in **Table 3** indicate that as the phase increases, there is a significant decrease in balance scores for the IS group, particularly in Phase 3 compared to the NS group. The difference across each phase lies in the rotational speed and diameter, which increase as the phase progresses. These results may occur because in IS, there is a disturbance in mechanoreceptor concentration, thereby disrupting the proprioceptive function of the limbs in both static and dynamic positions. Proprioception regulates muscle tension and strain control, which occurs not only in static conditions but also in dynamic positions. The resulting mechanical instability affects body balance. Therefore, balance assessment in patients is best performed using devices capable of dynamic movement, such as iMoove. In the management of lower limb injuries, rehabilitation to train balance is also essential.

Unfortunately, the iMoove device does not yet have clear reference values. As a pilot study, it is hoped that this research will yield reference values capable of classifying balance levels using iMoove. In this study, only two classifications were obtained: good (pass) or poor (fail). These classifications were derived from simple analytical calculations. **Table 3** shows a significant difference in phase 3 at a value of 8.2. It is at this value that a difference in ability between NS and IS is observed.

Conclusion

The average dynamic balance scores for normal soldiers are as follows: anterior 94.40%, anteromedial 98.13%, medial 97%, posteromedial 99%, posterior 94.67%, posterolateral 97.86%, lateral 86.53%, anterolateral 86.40%. These figures are presented as reference values for return to duty as well as for preventing injuries. The reference value obtained for iMoove is 8.20 in each phase. Dynamic balance scores in injured soldiers were lower than those in normal soldiers, even though assessments were conducted on the healthy leg in both groups. Medical rehabilitation therapy takes a holistic approach to the patient, addressing both the injured and uninjured parts with a focus on functional daily activities.

Acknowledgments

None.

Funding

None.

Author Contributions

All authors act as the guarantor of the manuscript. All authors fulfilled the ICJME authorship criteria and approved the final manuscript for publication. EE conceived the study, developed the research concept and design, conducted the data analysis, interpreted the findings, and formulated the conclusions. FAC, MFFS, DCT, and WKD contributed to study implementation, participant measurements, documentation, data entry, and manuscript drafting. All authors reviewed and approved the final manuscript.

Conflict of Interest

No conflict of interest.

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