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A Preliminary Study for Isometric, Isotonic, and Isokinetic Relationships in Vertical Drop Jumps at Heights on the Beam †

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Abstract: Muscle cramps often accompany a soldier's high physical readiness in a tactical environment. Close monitoring of the muscles is required during the downward jump training at a certain height, which combines isometric, isotonic, and isokinetic movements. In this paper, we propose a preliminary study on vertical jumps and forward and backward body postures to detect the onset of cramps. Six soldiers were divided into two groups of three subjects each: group one, forward fall jumps, and the other group, backward fall jumps. A high-resolution camera captured the movements, which were then analyzed using Kinovea software version 0.9.5. Downward jumps with the body backward are less likely to cause cramps, and muscle bands are recommended to prevent leg muscle cramps.

Keywords: soldiers; downward jumps; vertical height; muscle cramps

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1. Introduction

Leg muscle strength training is essential for a soldier's physical fitness. Leg muscle strength is trained through isometric, isotonic, and isokinetic exercises. Isotonic exercise is a static exercise; muscles contract and generate tension without changing the length of the muscle or the amount of joint motion [1]. Isotonic exercises are dynamic strengthening exercises with constant tension; muscles contract, lengthening (eccentric), or shortening (concentric) throughout the joint's range of motion, for example, push-ups and pull-ups [2]. Isokinetic exercises are controlled movements through joints at a constant angular speed; muscles shorten or lengthen with variations in tension [3]. Isometric exercises are muscle contraction exercises without joint movement or muscle shortening in the form of planks, wall sits, and glute bridges [4]. Physical exercise for soldiers is critical for maintaining their fitness and endurance. Military personnel's survivability is the foundation for a future military career and the performance of military responsibilities, and soldiers' everyday actions require a high degree of fitness training.

Soldiers build leg muscle strength by doing vertical drop jumps with their bodies facing forward and backward. Practice drop vertical jumping on soldiers in scenarios that require quick responses—a soldier's dedication in the face of events that require fast reactions [5]. This study employs two types of drop jumps: those with the body in front and those with the body in the rear, emphasizing variations in contact time and landing style. Three soldiers in the first group made leaps with their bodies facing forward. In the second group, three soldiers executed a rear body position leap on an inclined balancing beam crossbar at a height of 150 cm with bent knees (range of motion: 160–170°) in contact with the beam. The height was selected to enhance the activation of the knee extensors

when the participant jumped down with bent knees and the plantar flexors when leaping with extended knees and a short ground contact time.

Soldiers must be trained to perform drop jumps when faced with situations that require a quick response. During a vertical jump, movement is assessed from the angles of the waist, knees, and ankles [6]. Vertical drop jumps for a soldier are recommended to reduce the possibility of leg muscle cramps [5]. Muscle cramps are associated with overload and fatigue in overworked muscles [7]. Although these cramps can be treated easily with passive stretching, massage, active contraction of antagonistic muscle groups, or ice packs on the affected muscles, they are annoying during exercise. Adjustments to equipment configuration and selection (e.g., wearing shoes with thick socks), biomechanics, and relaxation techniques can help prevent or delay muscle cramps when jumping down an obstacle course [8]. The researchers proposed that using tape creates convolutions in the skin, leading to increased blood flow and reduced pressure on mechanoreceptors, ultimately reducing the incidence of exercise-related muscle cramps [9]. To evaluate the possibility of cramps, use the knees primarily as the center of body balance when dropping vertical jumps and moving.

To evaluate the possibility of cramps, use the knees primarily as the center of body balance when jumping and moving. Observations of soldiers performing downward vertical jumps were carried out with a high-resolution camera [10] to obtain reliable measurements, and motion analysis data were checked with Kinovea. Kinovea from high-speed video measurements, 2D motion capture of linear and angular positions and velocities of the torso, pelvis, and lower limbs [11]. This preliminary study will examine vertical jumps down along with forward and backward body postures corresponding to isometric, isotonic, and isokinetic muscle contractions to detect the onset of cramps.

2. Literature Review

Military physical and tactical training maximizes a prospective soldier's operational performance capacity. Tactical training is designed to produce positive longitudinal adaptations [12,13]. The insight gained through measuring muscle performance capabilities includes physical readiness and the risk of injury during exercise. The basic obstacle course of military training for prospective soldiers involves using weapons and passing various obstacles that prospective student soldiers must complete within a predetermined time [14]. This training equips prospective student soldiers with excellent skills, agility, and physicality to support the main tasks in their next service, as explained in Figure 1.



Figure 1. Dexterity training over an inclined balance beam obstacle course [14].

An obstacle course involves running or jumping across obstacles in the open [15]. The barriers passed include low hurdles, high hurdles, triple ditches, flat balance beams, low walls, inclined balance level beams, sloping embankments with one ditch, teetering obstacles, and high walls [16]. This paper discusses how a soldier jumps and falls with his body facing forward and backward from an inclined balance beam. Jumping movements require good alignment and posture to obtain the most effective and influential movements while helping to prevent muscle imbalances, tension, and injury [17]. Alignment means positioning joints in the correct anatomical position, making movement more efficient, and reducing the risk of injury. Body posture is determined and maintained by muscle coordination, proprioception, equilibrioception, position, and joint function [18]. The wrist strategy applied to the ankle joint is important and essential [19] in maintaining postural adjustments. It involves appropriate use of the hip joint muscles at the ankle joint and an effective stepping strategy [20].

From a mechanical and functional activity perspective, the ankle, knee, and hip joints are important when jumping at a certain height. Maintaining a sufficient range of motion, strength, and proprioception is essential in providing shock absorption and balance control of movements in the lower extremities [21]. The ankle joint is regulated by ground reaction forces generated by contraction of the gastrocnemius, along with the peroneus longus muscle and the tibialis anterior muscle [22]. Minor changes in balance adjustments are achieved through the action of the muscles associated with the ankle joint; the body's movement around the ankle, acting like an inverted pendulum, corrects the position of the center of gravity [23]. Figure 2 illustrates that the muscle shortening-strain cycle is important in physical activity [24].

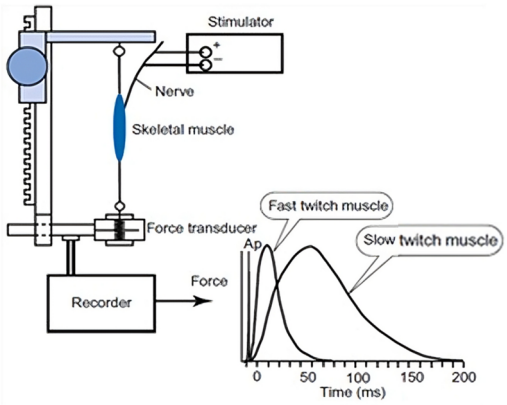


Figure 2. The shortening of the spring of this contraction is called an isometric contraction [24].

The stretch-shortening cycle is based on the idea that muscles can produce stronger, more muscular concentric contractions by preceding them with stronger, more muscular concentric contractions, as well as more robust, more muscular concentric contractions by preceding them with strong, solid, and rapid eccentric contractions [25]. Knee extension was performed with three different loading protocols: concentric contractions followed by passive stretches, concentric contractions preceded by isometric loads, and concentric contractions preceded by eccentric loads. In this context, "isometric" refers to muscular contractions that generate tension while maintaining a constant length [26]. "Isotonic" refers to a dynamic contraction in which a muscle shortens (concentric) or lengthens (eccentric) under fluctuating strain while moving against constant resistance [27]. Isokinetic contraction is when the muscle's tension during shortening is at its maximum across the range of motion, and the contraction speed is constant [28].

Isometric strength depends on muscle length or joint angle measurements, becoming more pronounced at shorter muscle lengths. Drop-in training requires varying training

methods. These training methods can be categorized as isometric, isotonic, and isokinetic [29]. They are developed for strength, endurance, and power [30]. Typically, training studies will last about eight weeks or longer, extending up to ten to twelve weeks [31]. Only a few reports have been conducted with shorter training programs. Several studies have compared the effects of isotonic training with isokinetic training on drop performance or power output measurements. Knee and ankle angles were controlled for all subjects during two familiarization sessions using Kinovea version 0.9.5 (a video annotation tool for sports analysis) [10]. Kinovea 2D digitization software was utilized based on standard surveillance video (30 Hz, 640 × 480 pixels) to capture the kinematics of the lower extremities [11]. Experienced researchers provided instructions during the training program on the required range of motion of the knee and ankle joints (visual inspection). Moreover, the training sessions are randomized, and the participants are different.

3. Methodology

3.1. Subjects

Six soldiers participated in this study (mean SD: 22 ± 3 years, 168 ± 8 cm, 66 ± 5 kg), performing a fall jump from a high platform in a basic military training obstacle course for prospective soldiers. The soldiers were placed into two groups to perform a vertical drop jump—healthy participants with no gait abnormalities. The Regional Ethics Committee approved the study, and all subjects signed an informed consent form.

3.2. Validation System and Video Calibration in Kinovea Software

The research method is an observational methodology that employs a high-resolution camera to capture the movement of the soldier's leaping posture at a vertical height, with the body positioned forward and backward. The recording angle and cross-section determine the camera's location, with the camera lens oriented parallel to the subject's height [10]. Version 0.9.5 of Kinovea software was utilized to analyze the video footage [11]. The relative knee angles during the leap were examined.

Calibration in Kinovea software uses lines with the camera positioned parallel to the motion plane and the optical axis perpendicular to the falling plane. Shishov et al. [10], the data parameters for Kinovea include video filtering at 20 Hz, video calibration with a 2D grid, vertical video position, and velocity with a root mean square error of 0.050 m (9%) of a signal amplitude of 0.22 m/s (7%), and horizontal video position and velocity with a root mean square error of 0.035 m (6%) of a signal amplitude of 0.16 m/s.

3.3. Experimental Set-Up

The camera is placed on a tripod at a distance of 150 cm to produce good footage of the jump movement from a platform height of 150 cm perpendicular to the middle of the track at 300 cm, as shown in Figure 3.

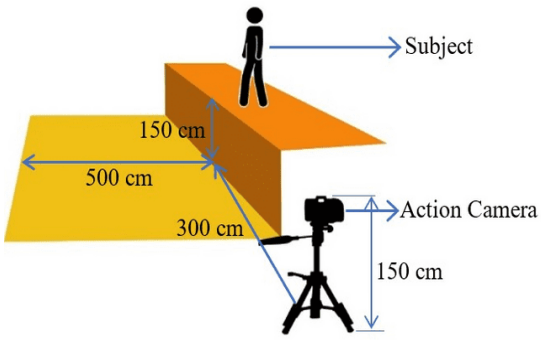


Figure 3. Motion, camera position, and field of view calibration area protocol.

This setting ensures calibration of the subject's lower body. Good lighting enhances the quality of the recording [32]. The cameras are configured to produce clear and sharp images [33].

3.4. Experimental Protocols

Subjects were instructed to drop jump from a high platform and land at their average speed, analyzing the subject's movement phase while landing in a stable posture. Group 1 comprised three participants who leaped forward; in Group 2, three dropped backward. Each subject performed the repetition five times. The drop jump movement forward and backward follows the same jumping phase in Figure 4, which includes (1) heel up, (2) squat, (3) push, (4) jump, (5) land, (6) second squat, (7) second push, (8) second jump, and (9) second landing.

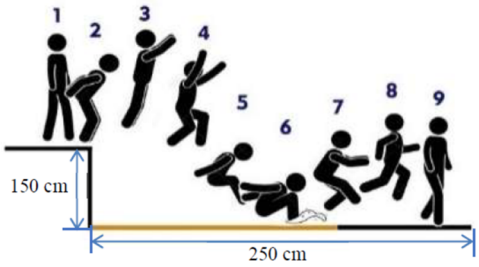


Figure 4. Phase jump at a vertical height.

The drop jump movement phases are recorded sequentially to produce video recordings, and each movement phase is analyzed using the Kinovea software. Subjects one, two, and three jump with their bodies positioned forward; subjects four, five, and six jump with their bodies positioned backward. Movement markers are placed on the toes, ankles, knees, and waist to obtain a relative knee angle [33]. Knee kinematics, or center of rotation (COR), is assessed during a drop jump to quantify the movement of the femur axis relative to the tibia and sole of the foot [34]. The average location of the COR sagittal plane on the beam is determined during the standing phase, starting with the tip of the foot and progressing to the tip of the lifted foot, as shown in Figure 5.

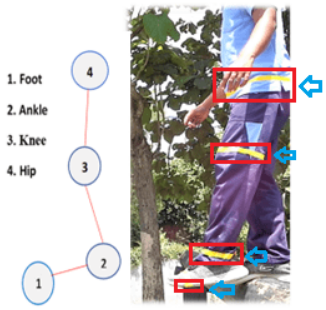


Figure 5. Scout light marker placement position.

3.5. Motion Tracking Using Kinovea

All previous video footage is played back to check for errors [35], the Kinovea software processes all video output data, and low-quality footage is not processed. The first video calibrates the dimensions accurately by creating a scale line representing height and distance dimensions. Before the researcher performed the leap in Figure 5, calibration lines as markers were inserted in the subject area spanning (1) foot, (2) ankle, (3) knee, and (4) hip, with four markers placed on the subject [36]. Kinovea tracks marker movement for all drop jump catches. The tracking and output procedures in preparation for the drop jump are in Figure 6.



(**a**) (**b**)

Figure 6. (**a**) Forward drop jump; (**b**) backward drop jump.

3.6. Angle Measurement

The relative knee angle was measured using the Kinovea program with four marker points [37], and the position of the leg muscles was examined [38]. The two markers beside the knee provide an angle relative to the subject's knee. The relative knee angle varies throughout the leap, depending on the motion phase [39]. The parameter used in this investigation is the change in angle to the motion jump phase [40]. The observed subjects retain experimental data.

3.7. Statistical Analysis

In statistical analysis with $n < 50$, the data prior analysis had met the normality requirement of the Shapiro–Wilk test and the homogeneity of the Levene test ($p \geq 0.05$). Kinematic outcome measures were tested using two-way ANOVA with knee angle as the dependent factor and factors between drop jump and phase. Statistical significance was set at $p \leq 0.05$. Statistical analysis was performed using IBM SPSS Statistics v.21 (SPSS Inc., Chicago, IL, USA) and the Bonferroni post hoc procedure to identify pairwise differences between means.

4. Result and Discussion

A soldier compares a forward and a backward strategy for initiating a drop vertical leap and determines whether any changes in platform height are likely to cause cramping. This work examines knee kinematics as COR during a drop jump to assess jump and landing kinetics, interlimb kinetic symmetry, and jump performance, as in Table 1.

The average knee angle for a drop leap vertically was (117.04 ± 14.64 degrees) forward and (127.65 ± 10.19 degrees) backward, with a significant difference ($p < 0.0001$) between the two directions. During an isometric contraction, the forward direction had a lower peak knee angle (157.4 ± 11.1 degrees) than the backward direction (163.4 ± 8.0 degrees), while the forward direction exhibited a higher peak knee angle at landing (155.3 ± 15.0 degrees) during an isokinetic contraction. The angle during the second push of phase (phase 7), when the muscle contraction state is isotonic for forward (108.6 ± 16.0 degrees), is substantially lower than for backward (111.6 ± 11.4 degrees). During the second landing (phase 9), when the muscle contraction state returns to isometric, the forward knee angle (140.6 ± 14.6 degrees) is significantly lower than the backward knee angle (149.4 ± 12.0 degrees).

The average knee angle during the vertical drop jump did not account for most muscle and tendon structural variations in the knee extensors and plantar flexors. The muscle and tendon structures of the plantar flexors during forward and backward estimating jumps was responsible for 8.29% and 30.42% of the variance observed when soldiers performed the vertical drop jump, respectively. Conversely, when the plantar flexors were joined

with the knee extensor structure, the difference in average variance between forward and backward leaps increased to 100% throughout the jump and second squat phases. This situation explains the jumping phase, in which the soldier attempts to move away from the beam, and the second squat, in which the soldier lands on the ground, as shown in Figure 7.

Table 1. Comparison of vertical drop jump positions between forward and backward when soldiers jump onto a beam from a height of 150 cm.

Dependent Variable: Knee Angle							95% Confidence Interval (Degree)		*p*-Value
Drop Jump		**Phase**	**Muscle Contractions**	**Knee Angle (Mean ± SD) (Degree)**			**Lower Bound**	**Upper Bound**	
Forward Drop Jump	1	Heel Up	Isometric	157.4 ± 11.1	117.04 ± 14.64		151.681	163.039	0.0001
	2	Squat	Isotonic	72.7 ± 8.7			66.998	78.357	
	3	Push Of	Isokinetic	77.4 ± 11.3			71.684	83.042	
	4	Jump	Isokinetic	131.9 ± 19.8			126.209	137.568	
	5	Landing	Isokinetic	155.3 ± 15.0			149.571	160.930	
	6	Second Squat	Isotonic	70.1 ± 18.6			64.427	75.786	
	7	Second Push Of	Isotonic	108.6 ± 16.0			102.879	114.238	
	8	Second Jump	Isotonic	139.6 ± 16.7			133.884	145.243	
	9	Second Landing	Isometric	140.6 ± 14.6			134.946	146.304	
Backward Drop Jump	1	Heel Up	Isometric	163.4 ± 8.0	127.65 ± 10.19		157.701	169.059	0.0001
	2	Squat	Isotonic	88.8 ± 7.4			83.128	94.486	
	3	Push Of	Isokinetic	136.9 ± 12.1			131.255	142.613	
	4	Jump	Isokinetic	142.7 ± 9.9			137.037	148.396	
	5	Landing	Isokinetic	153.4 ± 12.8			147.765	159.124	
	6	Second Squat	Isotonic	69.4 ± 9.3			63.683	75.041	
	7	Second Push Of	Isotonic	111.6 ± 11.4			105.898	117.257	
	8	Second Jump	Isotonic	133.2 ± 8.8			127.487	138.846	
	9	Second Landing	Isometric	149.4 ± 12.0			143.759	155.118	

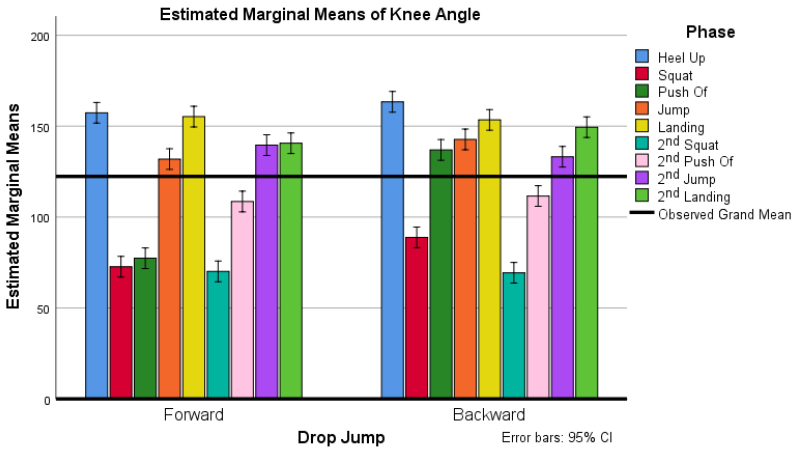


Figure 7. The average knee angle between forward and backward jumps.

The estimated variance difference during the heel-up phase was 38.75%, the squat was 17.57%, the push was 6.11%, the landing was 17.19%, the second push was 40.35, the second leap was 89.77%, and the second landing was 21.67. Although these figures appear to vary depending on the jump phase, it is worth noting that during the vertical leap, the estimated contribution of the plantar flexor in the landing phase was 17.57%, while the isokinetic muscle contraction and knee extensor in the second landing phase were 21.67%. Finally, the backward stance is a safe drop leap when weighing the potential of cramping against the choice of landing or second landing.

Data from Kinovea shows that the vertical jumping movement phase stages include drop jumping from a height and applying vertical jumping techniques involving jumping

positions and forward and backward bodies. The leg muscles during drop leaping versus isometric, isotonic, and isokinetic contractions are related to the soldier's physical balance and are measured by the relative knee angle across nine periods. Six soldiers performed vertical jumps down, divided into two forward and backward jump positions for five attempts, for a total of thirty trials to find the optimal drop-jump technique for body balance, as shown in Figure 8.

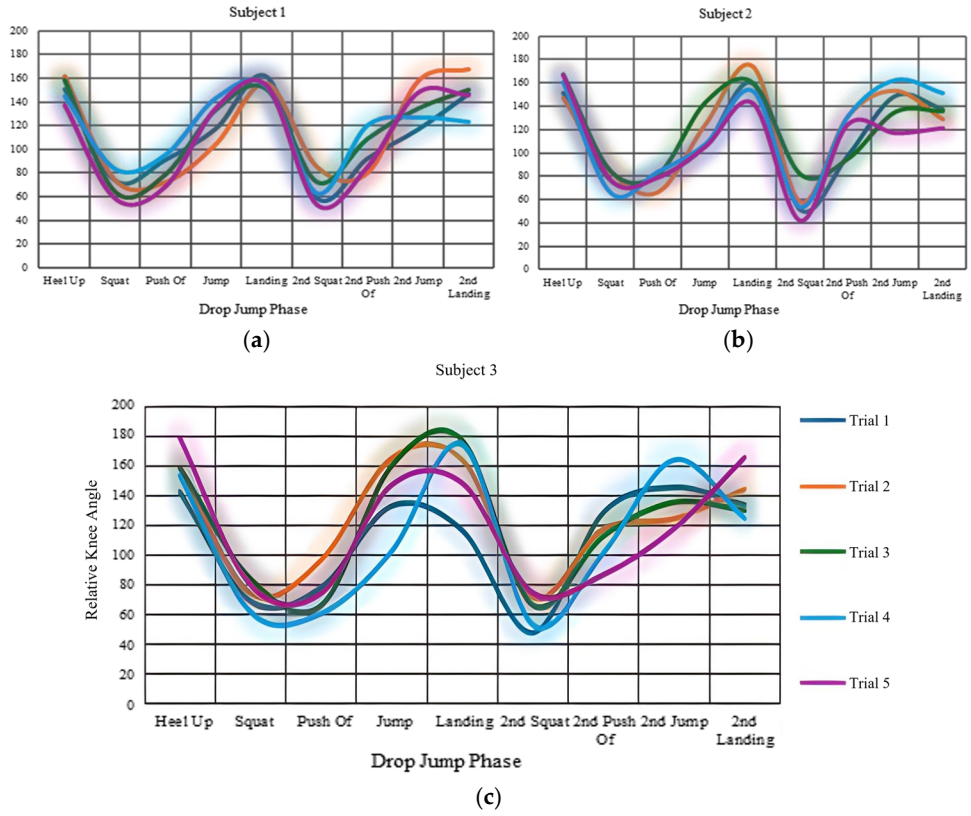


Figure 8. Relative knee angle in three soldiers (**a**–**c**) with a vertical drop jump position forward.

Each soldier leaps five times, taking a 20-min break between repetitions. Rest time is required to recover the flexibility of the leg muscles so that they do not alter the tension of the muscles when recorded together. Figure 9 depicts an analysis of the relative knee angle for the body's position when drop jumping forward.

Drop jumping soldiers with a forward body position are more likely to experience cramps, as evidenced by the average squatting positions in the first and second phases of 72.68° and 63.31°, respectively; the relative knee angle is smaller than the drop jump with a backward body position by 88.81° and 69.36°, respectively. Isotonic workouts in leaping forward body postures allow the muscles to contract to endure falls caused by body weight and provide the power to do so. Isotonic leaping drops forward in body postures permit the muscles to contract to endure falls caused by body weight, energy, and muscular strength. Figure 10 shows the average knee angle for drop jumps in forward and backward position leaps.

Soldiers leap from a height of 150 cm, and their front body position increases the danger of cramping, as evidenced by average push-off stages 1 and 2 of 77.68° and 108.56°, respectively. The knee has a lower relative angle backward than the body, at 88.81° and 111.58°, respectively. The action propels the body forward as isotonic muscles contract and push the force of the body's weight, creating a shifting force. Muscles extend (eccentric) or contract (concentric) the range of motion at each joint.

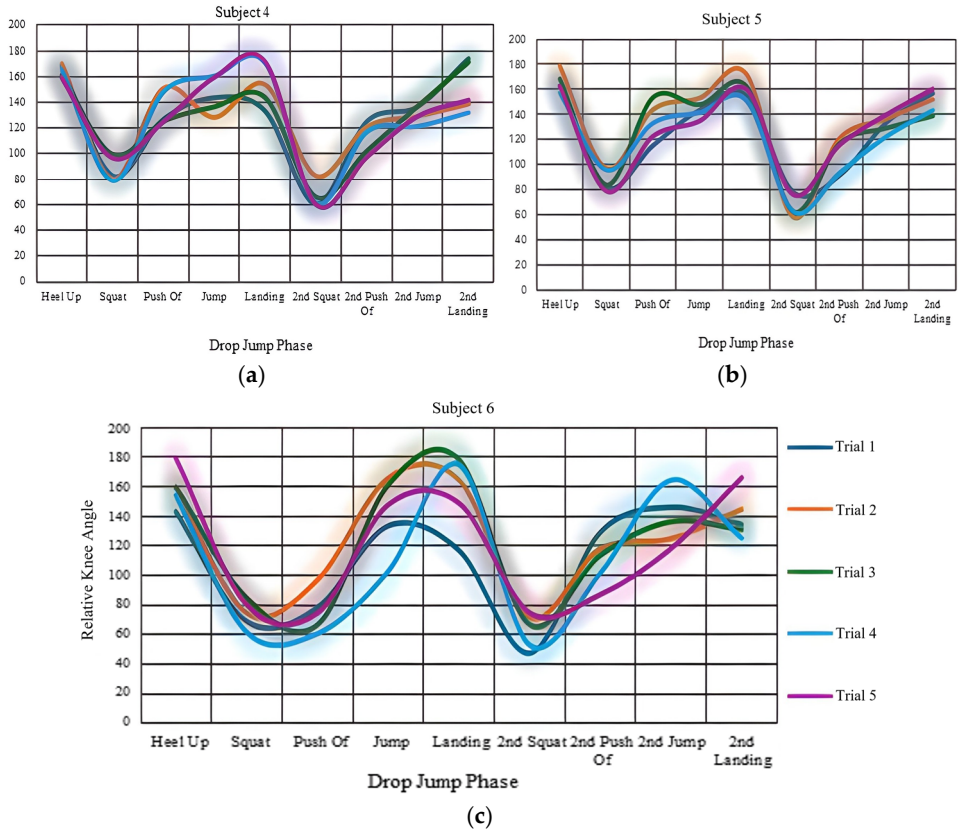


Figure 9. Relative knee angle in three soldiers (**a**–**c**) with a vertical drop jump position backward.



Figure 10. The average knee angle relative to the forward and backward body position drop jump.

The difference in the average relative knee angle of the high jump is shown in eight phases, with the forward body position having a lower angle value. Elongated (eccentric) or shortened (concentric) muscles are tighter and more prone to cramping due to excess weight. If the knee angle is modest, greater muscle contraction is required to retain and push the body—the difference in knee angle relative to the leap, as shown in Figure 11.

Figure 11 demonstrates that muscular contraction occurs when the muscle lengthens (eccentric) or shortens (concentric)—jumping at height is the consequence of isotonic, isokinetic, and isometric exercise, which is divided into eight stages between leaping from the forward and backward positions. In isotonic exercise, the muscles contract in four stages throughout the joint range of motion, with the heel-up phase leading to the squat phase and the landing phase leading to the second squat phase.

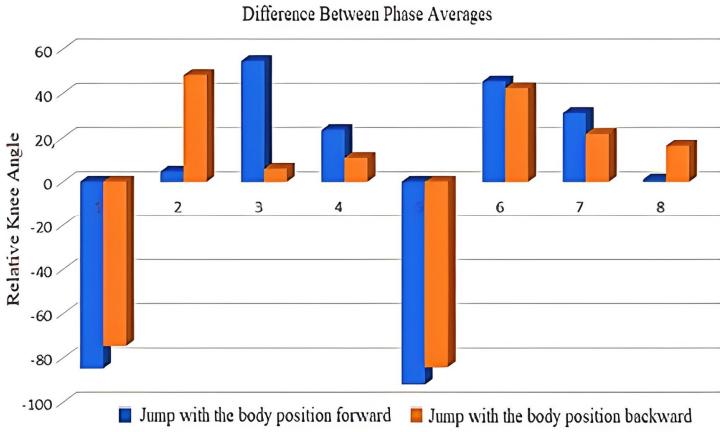


Figure 11. The average difference in relative knee angle in the drop jump.

The change in average relative angle for the forward leap from the heel-up phase to the squat phase reduces the relative knee angle to −84.68°, whereas the back jump is −74.57°. When you spring forward, your leg muscles contract more tightly, causing muscular cramps. On the contrary, placing the hands in front of the body during a backward jump improves body mass balance and helps to reduce the gravitational force exerted. Leaping from a height with the body positioned rearward is more regulated.

In isokinetic muscle training, the muscles in the legs contract at a constant angular velocity while the muscles shorten or lengthen. There are 4 phases in the isokinetic muscle training procedure cycle, where the two critical phases are the squat phase to the push-off phase and the push-off phase to the jump phase. The average angle relative to the squat and push phases for the front jump is 4.68°, while the back jump is 48.13°. The average difference between the push-off and jump phases for the forward drop jump is 54.53°, whereas the backward jump is 5.78°, meaning that the backward drop jump is considered safer than the forward drop jump.

In isometric exercise, the leg muscles contract at a constant angular velocity while the muscles shorten or lengthen. There are four phases in the isokinetic training procedure cycle, where the two critical phases are the squat phase for the push-off phase and the push-off phase for the jump phase. The average relative angle of the squat phase to the push phase for the forward drop jump is 4.68°, while for the backward drop jump is 48.13°.

The average difference between the push-off and leap phases for the forward drop jump was 54.53°, whereas, for the backward drop jump, it was 5.78°, indicating that drop jumping backward was deemed safer against cramping than drop jumping forward. Meanwhile, the forward jumping movement is concentrated on the knees, the lower body's balancing point. As the hands travel forward from the body's center of mass, their mass is equal to the body's weight multiplied by the gravitational force.

The difference in muscular contraction is that springing forward places the body in greater danger of muscle cramps caused by excessive muscle tension. Muscle tape is advised as an exercise aid because it reduces the risk of muscular cramping [9]. Further study led to the development of muscle tape for the leg muscles. This tape is placed around the ankle muscles to prevent excessive contraction.

5. Conclusions

The results of the preliminary study indicate that the drop vertical jump at a certain height for soldiers requires controlling the back against changes in the relative knee angle of the nine phases. The average angle is relatively greater in the backward drop jump than in the forward drop jump of the seven phases, meaning that changes in the lengthening

(eccentric) or shortening (concentric) muscles throughout the range of motion of the joints are not too tight.

The position of landing on the ground to drop jump backward is more recommended during an emergency because the hands will help improve the balance of body mass, and the magnitude of the gravitational force will be balanced by swinging the arms, ensuring that the isokinetic in the knee muscles of the legs provides the same load and tension.

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