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Analysis of Landing Characteristics in Jump Heading Techniques of Indonesian University of Education Soccer Club Players

Febrian Yusran Saputra[1]✉, Agus Rusdiana[2], Tono Haryono[3]

Departement of Sport Science, Faculty of Sport and Health Education, Universitas Pendidikan Indonesia, JL.Dr. Setiabudhi No 229 Bandung, 40154, Indonesia[123]

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Abstract

Fatigue is a common component in soccer matches, and can lead to reduction of movement quality and enhanced injury risk, particularly in the jump heading technique that requires high levels of coordination and postural control. This study was conducted to examine the biomechanical parameters of landing in the jump heading techniques before and after fatigue on players of Indonesian Education University (UPI) Football Student Activity Unit. The design for the study was a non-experimental research design and quantitive in method. Ten male collegiate soccer players were the participants of this experiment who executed the jump heading right before, and immediately following, completion of a lower extremity fatigue protocol. The studied kinematic variables were jump height, knee flexion angle and trunk position at take-off, landing force (measured using high-speed video analysis [SkillSpector] and force plate). One Good: One Bad Approximately 1000-Fold Ahi Attenuation Deriving from Real Pauli Admixture Analysis was carried out using a paired statistical test (α = 0.05). Fatigue did not appear to influence jump height and landing force, with significant knee flexion angle in take-off and trunk postural control were increased and decreased respectively. These results suggest the presence of compensatory biomechanical mechanisms related to fatigue. It was determined that fatigue affected alterations of some kinematic variables associated with balance control and movement quality during the jump heading technique. As a result, conditioning should likewise focus on the control and endurance of posture, core stability and neuromuscular function to preserve movement quality but also limit injury under fatigue.

How to Cite

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✉ Correspondence Author:
E-mail: yusransptra@gmail.com

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INTRODUCTION

Biomechanics is that science of structure and function of biological systems by means of the mechanics. (Pavlasová et al., 2025) Sports biomechanics is a branch of biomechanics specifically that advances the knowledge of the sports performance and exercise. The objective is to "look at how the body moves and make sure I'm moving in the way that is most efficient and effective to us but also minimizing risk for injury when you're in races or activity. (Hewett & Bates, 2017)

Some technical elements in soccer are involved in two BI processes, as "movement without ball" and "movement with ball". Off-the-ball movements: Off the ball movement refers to the physical and mental activities of a player that are performed without possessing the ball, these are generally when players move in general or receive away from their mark. In addition to the other means of moving with the ball (the kick-passing), there is kicking connection, reception of a pass or shot on goal, heading, dribbling with feints in control and running with the ball simultaneously with tackling and throwing-ins/ keep-ups for goalkeepers. (Arastoo et al., 2014). In soccer, using the head is one of its important fundamental techniques because this skill is frequently used by players to pass the ball, defend against opponents' attacks and shoot a score (Scoppa, 2015).

The mechanistic procedures of jumping headings can be described as below. The player then jumps toward the ball, adopting a neck extended position at impact as the body approaches the top of its jump before snapping it momentarily pulling back while contracting neck muscles. The target is the ball, and the eyes are locked on it. Then, the chin is tucked closer to the neck, abdominal muscles tighten and back of pelvis and body thrusts forward so that forehead strikes ball full on. Once the ball is contacted, the body leans slightly forward (to stay balanced), and a controlled explosion to both feet allows for less of a chance or additional risk to injury. (Marqués-Jiménez et al., 2017)

Jump heading can result in higher vertical GRF, greater knee extension, and lower initial knee flexion angle compared to standard stop-jump tasks in both genders. Knee flexion decreases, GRF increases, thereby elevating injury risk (Barakat Alfayyadh, n.d.)

We conclude that kinematic control has a major influence on the accuracy of heading behaviour. Another research conducted by,(Akbari et al., 2023) demonstrates that the addition of heading in a vertical drop jump task changes body kinematic strategy and enhances the risk factors for injury in particular knee. That is what I mean to express by saying that this involves movement coordination and postural equilibrium. Compared with non-professional players, professional players have better postural control with respect to differences in skill level. (Broglio et al., 2004)also found that while heading does not necessarily induce acute changes on postural control but the body stability can be altered following repeated exposure.

Players exhibit a lower initial knee flexion angle, higher ground reaction force (GRF), and more negative extension moment during jump heading landings. These biomechanical changes, including knee valgus and tibial internal rotation, can increase anterior tibial shear force, directly implying risks to knee ligament injuries, particularly ACL (Mahdieh & Lenjannejadian, 2024). ACL injuries are among the most common in soccer, particularly those resulting from jump heading that increases ground reaction force (GRF) and knee stress, leading to decreased performance and potential injury risk (John et al., 2025)

The effect of fatigue on knee flexion angle, trunk position, and landing force in jump heading technique. What mechanisms occur in landing biomechanics under fatigue conditions in soccer players. Is there a significant difference in the landing phase of jump heading technique before and after fatigue.

Analyzing kinematic changes in (jump height, knee flexion, trunk flexion, and landing force) before and after fatigue. Identifying changes in body posture and movement quality due to fatigue. Recommending exercises to develop specific jump heading training to reduce injury risk.

This study is unique because it specifically investigates the biomechanics of fatigue effects on landing in the jump heading technique among 10 male soccer players from Universitas Pendidikan Indonesia (UPI), utilizing a combination of SkillSpector analysis and force plate to measure kinematic variables such as jump height, knee flexion angle, trunk position, and landing force. Unlike previous research focused on general vertical jumps, this study addresses literature gaps by emphasizing specific compensatory mechanisms due to fatigue; furthermore, it employs a lower body fatigue protocol consisting of counter movement jumps, lateral bounds, drop jumps, and side steps each performed in 3 sets until exhaustion while verifying fatigue through blood lactate levels to strengthen physiological validity. The study not only focuses on preventing ACL injury risks associated with jump heading but also supports the development of specific jump heading training programs to maintain performance and safety under fatigue conditions.

METHOD

This study employs a comparative method and a quantitative approach. The research design is a quasi-experimental study aimed at analyzing landing mechanics in the jump heading technique.

Participants The subjects were soccer players from Indonesian University of Education's youth team. The sample was purposive (which sought information-rich cases) drawn from those who fulfilled the inclusion criterion of active player volunteer to participating in all research activities.

This study includes two variables; the IV (the players' condition- lower body fatigue) and the DV (landing characteristics on his or her jump heading, which occurred through knee and hip angles at take-off and landing part), knee and hip angular velocity, jump height, the torso position when jumping as airborne, ground contact time duration of ground reactions force.

The equipment included a high-speed camera (120–240 fps) to capture jump heading movement, SkillSpector (as motion analysis tool to measure the degree and angular velocity of joint angle), a force plate to measure ground reaction forces in landing, and lower body test instruments such as squat or leg press tests with designated amount of repetitions and weight used for induction of lower body muscle fatigue.

Data collection procedure At onset, the researcher explained the purpose and procedures to be followed to the participants. Participants completed a jump heading test consisting of a vertical drop jump from a 30 cm height box with the distance from box-to-force plate set at 50% participant height. Subjects performed maximal vertical jump for header shots of a ball on suspension at head level. Landing data were filmed and recorded using a force plate. A fatigue protocol with a lower body test is used, e.g. repeated squatting with a weight until muscle fatigue (expressed as either maximum number of repetitions or on a subjective scale) is achieved. After the fatigue test blood lactate levels of the subjects are measured with a lactate meter to quantify physiological fatigue. After verifying the fatigue status based on lactate test results, the jump heading test was repeated following same process to measure post fatigue status (Table 3).

Descriptive statistics were calculated to characterize the landing. We tested normality with the Shapiro-Wilk test. Conditions were compared before versus after fatigue: paired t-test (normal data) or Wilcoxon test (non-normal data). Statistical significance was defined as $p < 0.05$.

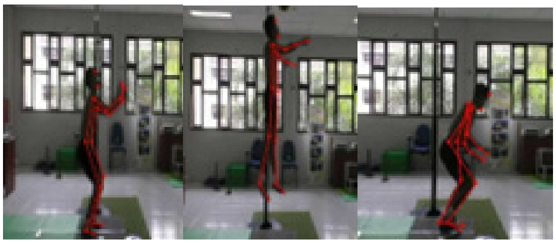

Figure 1. Jump height
Source : Skill Spektor.

RESULTS AND DISCUSSION

Table 1. Data on participants (age, height, body mass, and BMI).

N	Average ± Age (years)	Average ± Height (cm)	Average ± Body Mass (kg)	Average ± Body Mass Index (BMI) (kg/m2)
10	19.3 ± 0.46	168 ± 6.4	64 ± 4.1	24 ± 0

According to the **Table 1** of research subjects characteristics, the number of all male soccer players from Indonesian University of Education Student activity units who served as participants consisted ten person with average 19.3 ages in range between 19-20 years old. Players were relatively short in height (average 1.68 m±0.032), built with an average body mass of 64 kg and BMI =24 kg/m², thus normal to near ideal body weight according to WHO classification. Small between-subject variation in age (0.46), height (6.4 cm) and body mass (4.1 kg) was of evidence for the homogeneity of physical characteristics among players based on the standard deviations of these variables. Generally, this data indicates that the research sample is in proportion and uniformity with regard to physical conditions, thus can be adapted for a more accurate and representative study of the biomechanical characteristics of landing in the jump heading technique.

According to the **Table 2** with lactate level data, the measurement values were determined on ten people before (Lactate 1) and after such jump heading activities (Lactate 2). The mean initial lactate level (Lactate 1) was 3.02 mmol/L ± 0.79, the increase after activity was up to 13.78 mmol/L ± 3.89. This elevation demonstrates remarkable lactate produced after high intensity activity , implicit that the anaerobic energy system is dominant during performance of jump heading. The elevated final lactate demonstrates increased muscle fatigue in the legs and upper body necessary to propel (jump) and stabilize (land) the jump. In general, these data indicate that jump heading activity leads to an increase of anaerobic metabolism and elicited physiological responses indicative of high level muscle effort in players.

Table 2. Subjects' lactic acid data.

Subject	Laktat before (mmol/L)	Laktat after (mmol/L)
1	2,9	9,6
2	4,1	15,6
3	3,8	14
4	2,5	8,1
5	3,6	15,4
6	1,8	9
7	2,1	11,5
8	2,1	15,8
9	3,7	20,1
10	3,6	18,7
Mean	3,02	13,78
Std.D	0,79	3,89

Table 3. Kinematic variables during pre-fatigue and post-fatigue conditions.

Kinematics analysis variables	Mean and SD	sig. (p value)		information
		Before fatigue	After fatigue	
Jump height (cm)	2.13 ± 0.110	2.05 ± 0.132	0.061	
Knee flexion take off (deg)	122.82 ± 9.425	130.82 ± 10.603	0.030*	Significantly
Trunk flexion take off (deg)	188.96 ± 72.108	101.09 ± 46.056	0.003*	Significantly
Feet landing (N)	8.84 ± 1.010	8.26 ± 0.808	0.085	

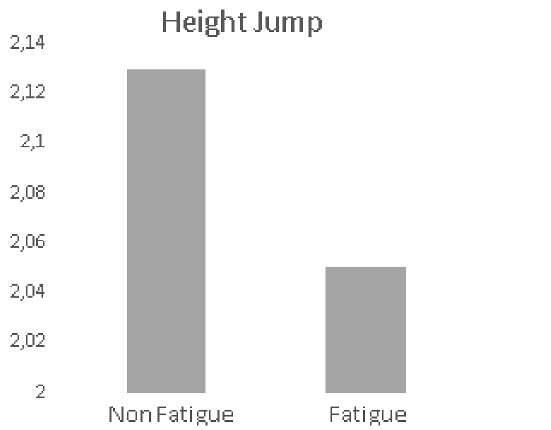

Figure 2. Differences in jump height under non-fatigue and fatigue conditions.

According to **Table 3**, the kinematic differences observed pre- and post-fatigue were of differing nature for every variable. Jump height decreased by a mean of 0.080 cm from pre'= 2.13 ±'0:110 cm to after fatiguing exercise (p = '.061 which was not significant), therefore, it appears that fatigue had no effect on the ability to produce jump height. However, the knee angle at take-off significantly increased from 122.82 ± 9.425° to 130.82 ± 10.603° (p = 0.030), which suggested that the body intended to counteract muscle power decrease in order to carry on jumping performance as much as possible by compensatory strategy. The other major difference was detected in trunk flexion, which significantly decreased from 188.96 ± 72.108° to 101.09 ± 46.056° at very highly significant ($p = 0.003 < \alpha=0.05$), reflecting that fatigue appears to have a role in postural control during take-off phase, also means and SD values are indicated in Table-II of the results section below rather than being repeated here (Table-III). In contrast, landing force only reduced to 8.26 ± 0.808 N from 8.84 ± 1.010 N, and was not significantly different (p = 0.085), suggesting that force during landing may remain Stable under fatigue condition of body state.

In the initial period, the results of this study demonstrate that fatigue affects each kinematic aspect of jump heading in a different way, demonstrating how complex is the body's adjustment when physical ability starts to decrease. Fatigue is a factor that does not only effect the muscles of which are the main actuators but also affects muscular coordination, i.e., body segments coordination and sensory motor integration that play roles in movement accuracy (Hamdan et al., 2025). Under such stressful condition, the neuromuscular system automatically adjusts muscle recruitment patterns to sustain movement EF at lower efficiency levels (Vermeulen et al., 2023). This adaptability is readily visible in complex movements which demand abilities of strength, speed and balance control (Shan et al., 2024)As a result, fatigue serves as an agent that changes movement strategies from ideal patterns to compensatory movement towards preserving continuity of the motion.

One simple adaptation strategy is observed for the take-off phase. As the physical resources of the body start to fade, athletes tend to alter their running style/biomechanical strategy in an attempt to take some pressure off weakened muscles and still produce similar levels of vertical force. The body will compensate, changing the angles of articulation in its joints and it muscular recruitment pattern and rhythmic movement to maintain the ability to generate suitable thrust. Repackaging of this strategy is exemplified by the endeavor to enhance natural WADA-related DNA methylation resulting from ageing or overtraining and is a players resource for maintaining performance during macrocycles despite suboptimal physiological state (Geiger et al., 2024). During heading performance, the take-off phase is critical for quality of ball contact, and therefore it is necessary to adapt the movement in place to achieve the same goal if energy utilization becomes less efficient as a consequence of increased fatigue (Rusdiana et al., 2020).

Fatigue is apparently of greater influence during the posture controlling phase. A decrement in being able to maintain an upright trunk position implies a disturbance of the balancing system that is believed to stabilize jumping movements at (Du & Fan, 2023)This state is the fundamental indication that fatigue effects are not only local and against muscle strength but that they also involve the components of proprioceptive sensors, which play a role in correctly regulating body position (Bafrouei et al., 2025)In the presence of defective postural control function, the entire body has an issue maintaining movement congruity among the trunk, center of mass and lower extremities which can lead to less effective motion while also potentially disrupting global mechanics (Gebel et al., 2022)"This is relevant because the stability of the torso when applying force seems to be an essential aspect with respect to power production, as well as for landing safely.

The body's response in the landing phase also offers significant data on the role of fatigue on body kinetics following a jump (Li et al., 2025). While the landing pattern seems to not change much, the changes observed signify a reduced force absorption capability that is usually maintained by muscle strength and timing of leg muscle activation (Wong et al., 2020). As fatigue begins to set in, coordination between the ankle, knee and hip joints are no longer efficient absorbing ground reaction forces. It may place passive structures such as ligaments or bones under more stress, notably when the movement is repeated vigorously (Zhang et al., 2021).Therefore, minor alterations in landing patterns might be sensitive for an increase of the risk of mechanical stress that may ultimately result in injury.

Changes in kinematic parameters with fatigue are further evidence that the biomechanics of jump heading techniques need to be considered, particularly when performing movements in high-intensity game situations (Hardwis et al., 2024)As such they demonstrate that training is not just about getting stronger and more powerful, but about developing postural control, central stability and the ability to "hold positions" even when under fatigue. Athletes who can sustain quality of movement when fatigued are more reliable performers and relatively free from injury risk (Alimoradi et al., 2024).Thus, the findings of this study can be used by coaches and sport practitioners as part of a broad program to improve athletes' physical and technical preparedness such as to develop more holistic types of training, including stabilization exercises and neuromuscular endurance training or simulating game activities.

CONCLUSION

Our investigation demonstrates that fatigue has a pronounced influence on various kinematic variables of jump heading, particularly to knee flexion angle and postural control at the trunk regarding take-off. No meaningful difference was observed for both jump height and the landing force the increase in knee flexion angle slightly increased, and on contrary, trunk flexion relevant decreased much these changes suggested a biomechanical compensation with reduced neuromuscular capacity. These results support the notion that not only force production but also postural stability and movement economy are disrupted by fatigue, which might elevate the risk of injury incurred when heading.

The findings of this study highlight the need to keep standard jump heading technique in fatigued states, since performance under match demands regular high intensity. Training which promotes enhancement in from postural control, core stability, and neuromuscular endurance is necessary for the prevention of potential athletes loss of the ability to preform optimally or safely. Expectations for reducing risk of injury and maintaining in-game performance during competition will be managed through a comprehensive training program.

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