EFFECTS OF DYNAMIC KNEE VALGUS ALIGNMENT ON GROUND REACTION FORCE AND KNEE MOMENT DURING LANDING

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This study examined the impact of dynamic knee valgus alignments on vertical ground reaction force (vGRF) and knee moment in 33 male collegiate athletes during a single-leg vertical jump from a 30-cm box. Categorized into valgus (n=12), neutral (n=8), and varus (n=13) groups based on knee angular displacement during landing, participants were analyzed 100 milliseconds immediately after initial ground contact. Normalized results indicate that the varus group demonstrated higher peak vGRF and maximum knee moment compared to the valgus and neutral groups. No significant differences were found in parameters like time to peak vGRF, loading rate, and peak hip moment. Our findings highlight the exacerbating effect of dynamic knee varus on landing impact, providing crucial insights for clinical applications and future research.

KEYWORDS: lower limb malalignment, neuromuscular deficits, knee varus

INTRODUCTION: The anterior cruciate ligament (ACL) injury is common in sports such as basketball, volleyball, soccer, and badminton (Montalvo et al., 2019). It represents the most prevalent ligament injury in the knee joint (Larwa et al., 2021), with approximately 70% to 80% being non-contact injuries occurring during jump landing, pivoting, or cutting movements (Montalvo et al., 2019). Previous studies identified four common landing movement characteristics associated with ACL injuries, including knee valgus, stiff landing posture, weight concentration on the injured leg, and trunk tilt causing the center of gravity to be outside the base of support (Hewett et al., 2005).
Dynamic knee valgus, characterized by hip adduction, hip internal rotation, and knee abduction, is recognized as a prevalent lower extremity alignment in non-contact ACL injury situations (Wilczyński et al., 2020). Research indicates that knee valgus during jump landing increases tibiofemoral joint stress and the occurrence of patellofemoral pain, elevating the risk of lower limb injuries such as iliotibial band syndrome, acute lateral ankle sprains, and chronic ankle instability (Crowell et al., 2021).
In assessing dynamic knee valgus during landing, the drop vertical jump is a common testing protocol with high reliability (intra-class correlation coefficients > 0.93) (DiCesare et al., 2019). Moreover, our research adopted a single-leg task for its proven effectiveness in assessing lower limb biomechanics related to ACL loading and the risk of patellofemoral pain syndrome (Ali et al., 2013). Single-leg tasks offer greater sensitivity in identifying individuals at elevated injury risk compared to double-leg tasks (Mauntel et al., 2014), owing to their increased demand on neuromuscular control and balance. Furthermore, focusing on dynamic knee valgus during single-legged tasks provides specificity and enhances practical relevance for injury prevention strategies. However, the specific biomechanical effects of different dynamic knee valgus alignments remain unclear. The aim of this study was to investigate the effects of three dynamic knee valgus alignment (valgus, neutral, and varus) on ground reaction force and knee joint torque. Our hypothesis posited that individuals in the valgus and varus groups would demonstrate higher peak vGRF and knee moment, attributed to their pronounced dynamic knee valgus alignment in the frontal plane, in contrast to the neutral group.

METHODS: Participants (N=33) were categorized into three groups based on knee angular displacement during landings: valgus group (n=12, valgus angle= 4°~ 6°), neutral group (n=8, valgus angle = -1°~1°), and varus group (n=13, valgus angle= - 6°~ -2°). Building upon prior research (Werner et al., 2019), our study utilized a two-dimensional frontal plane motion analysis method to assess dynamic knee valgus alignment. Data collection involved the use of a Mega high-speed camera (240 Hz) synchronized with an AMTI force plate (1,200 Hz) during a single-leg drop vertical jump on the dominant foot. The dominant foot was determined by the kicking foot. Twelve reflective markers were placed on specific anatomical landmarks (Wilczyński et al., 2020), and each trial involved two stages: first, barefoot landing after single-leg dropping down from a 30 cm box; and second, barefoot landing after a maximal vertical jump rebounding from the first drop. Trials continued until five successful ones were recorded, excluding those with balance loss during landing. Kinematic data was analyzed using Kwon 3D motion analysis software (Visol, Gwangmyeong, South Korea). The initial impact (INI) phase of landing was defined 100 milliseconds immediately after initial ground contact (vGRF reached more than 10 N). Norcross et al. (2013) reported that peak kinetics proposed to contribute to ACL loading usually occur during the initial 100 milliseconds of landing and, therefore, were identified during the INI of landing. Kinetic data (GRF vector, centre of pressure) were low-pass filtered at 10 Hz with a fourth-order, zero-phase-lag Butterworth filter and combined with kinematic, anthropometric, and inertial parameters to calculate the internal joint moments at the hip and knee using inverse dynamics. The joint moment analysis was conducted using MATLAB software (version 9.10). Peak vGRF(the peak of the first landing) and joint moments were normalized to body mass, BW and Nm/kg, respectively. One-way ANOVA independent samples compared differences among the valgus, neutral, and varus groups. If any significant differences (α=.05) were observed, Bonferroni post-hoc analyses were conducted for all tested variables.

RESULTS: Table 1 presents the statistical results of this study. At the peak vGRF, the varus group exhibited greater values than both the valgus and neutral groups. Similarly, at the maximum knee moment, the varus group surpassed the valgus group. Nevertheless, no significant differences were observed in the time to peak vGRF, loading rate, and peak hip moment.

Table 1: Peak vGRF, peak knee moment and peak hip moment during landing for three dynamic knee valgus alignment.

	Valgus group	Neutral group	Varus group	*F*	η_p^2
PvGRF(BW)	2.44 ± 0.24[a]	2.53 ± 0.21[b]	3.04 ± 0.36	15.55*	.51
Time to PvGRF(s)	0.084 ± 0.01	0.085 ± 0.013	0.091 ±0.01	1.78	-
Loading rate(BW/s)	29.93 ± 5.26	30.57 ± 5.74	33.87 ± 5.56	1.80	-
Peak knee moment (Nm/kg)	0.65 ± 0.54[a]	1.22 ± 0.74	1.77 ± 1.05	5.87*	.28
Peak hip moment (Nm/kg)	2.71 ± 0.55	2.69 ± 1.19	2.90 ± 0.97	0.20	-

Note: BW=body weight; PvGRF= peak vertical ground reaction force; [a] Significant differences between the valgus group and varus group, [b]Significant differences between neutral group and varus group; *p < .05.

DISCUSSION: This study aimed to investigate the effects of three dynamic knee valgus alignment (valgus, neutral, and varus) on ground reaction force and knee joint moment. The result indicated that the varus group exhibited greater peak vGRF in the frontal plane than both the valgus and neutral groups. Ground reaction force serves as a key indicator of the stress intensity experienced by the human system during ground contact (McClay et al., 1994). Particularly, the vGRF acting on the lower extremity joints elucidates the net force and joint moments experienced during the deceleration phase of landings. Our result revealed that individuals exhibiting dynamic knee varus experienced heightened knee extensor moment and peak vGRF compared to those with dynamic knee valgus. These findings suggest that landing with dynamic knee varus may amplify the impact on the knee joint during landing deceleration. Consequently, dynamic knee varus during landings could be a significant biomechanical factor diminishing an individual's ability to mitigate the impact on the knee joint. Previous research has underscored the role of the knee and hip joints as primary shock absorbers during landings

(Brown et al., 2016). Specifically, studies have indicated that the hip extensor, knee extensor, and ankle plantar flexor muscles contributed 38%, 41%, and 22% of the total energy absorption, respectively (Zhang et al., 2000). These results indicate that the peak vGRF in the varus group was apparently distributed to the hip joints without changing the total impact imposed on the body during landings. Various factors influencing the vGRF magnitude have been explored in numerous studies. These factors include gender, footwear (shod or barefoot), stiff surface (Niu et al., 2014), landing height (Peng, 2011), jump landing distance, and different landing techniques such as Parkour-style landings (Puddle & Maulder, 2013).
Additionally, our study observed a dual-peak vGRF pattern for participants in the neutral and varus groups who landed rearfoot. Considering the experimental definition focusing on the first peak vGRF, it was noted that the first peak was smaller than the second, suggesting an influence of forefoot and rearfoot landing patterns on the peak vGRF in our study (Puddle & Maulder, 2013).
Although the time to peak vGRF did not exhibit significant differences among the groups, the valgus group displayed a trend of shorter time relative to the other two groups. Hewett et al. (2005) suggested that individuals with knee valgus during landing experience a 16% reduction in stance time compared to typical subjects, potentially contributing to the observed shorter time to peak vGRF in the varus group. Furthermore, our study revealed that the maximum knee joint torque in the valgus group was significantly greater than that in the varus group. Previous research identified larger knee varus angles as predictive parameters for non-contact lateral ankle sprains, indicating that an increased knee varus angle leads to greater joint abduction moment (Mineta et al., 2021), aligning with our findings. Another study noted that a landing strategy primarily utilizing hip joint involvement resulted in lower knee joint abduction moment and a significant reduction in the percentage distribution of knee joint torque (Nguyen et al., 2018), aligning with our findings.
The limitation of this study included conducting experiments barefoot to avoid footwear-related variations, which may impact external validity as athletes typically wear appropriate shoes during sports activities (Niu et al., 2014). Although the study maintains good internal validity, the external validity is compromised.

CONCLUSION: The ability to attenuate the impact on the body during the deceleration phase of landings is crucial for achieving soft landings in the lower extremity joints. Our study demonstrated that landing with dynamic knee varus led to a greater knee extensor moment and peak vGRF compared to landing with dynamic knee valgus. To mitigate this risk, it is recommended to reduce angular displacement of the knee during landing. These findings provide a valuable clinical foundation for injury prevention strategies and serve as a reference for future research endeavors. Moreover, future research should emphasize single-leg tasks rather than double-leg tasks to better understand and address the causes and exercise training methods for reducing dynamic knee valgus in single-leg drop vertical jump landing. This highlights the importance of further exploration in this area to enhance our understanding and develop targeted interventions for injury prevention.

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