ESTIMATION OF ANTERIOR-POSTERIOR FORCE FROM VERTICAL GROUND REACTION FORCE IN COUNTERMOVEMENT JUMP TEST

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This study addresses the challenge of accurately estimating Horizontal Ground Reaction Force (hGRF) from Vertical Ground Reaction Force (vGRF) in the Counter-Movement Jump (CMJ) test. While vGRF is pivotal for quantifying vertical jump height, understanding hGRF provides insights into horizontal propulsion and overall jump efficiency. Athletes (n=40) who participated in the AIU Athletics championship were asked to perform the Counter-Movement jump in Kistler force plates. The force data was measured through bilateral Kistler Force plate model 9287CA with dimensions 1200x600x100 and analyzed using MARS software. Multiple regression in Microsoft Excel showed that the hGRF accounts for 49.96% of vGRF and is statistically significant. This research contributes to refining jump biomechanics understanding, aiding practitioners in extracting comprehensive insights from standard jump-testing protocols.

KEYWORDS: anterior-posterior force, vertical force, countermovement jump.

INTRODUCTION: The Counter Movement Jump (CMJ) test is a fundamental biomechanical tool for assessing an athlete's explosive lower limb power and vertical jump performance. While Vertical Ground Reaction Force (vGRF) is crucial for quantifying vertical jump height during CMJ, understanding the Horizontal Ground Reaction Force (hGRF) provides insights into horizontal propulsion and overall jump efficiency. Previous research emphasizes considering both force components for a comprehensive understanding of jump mechanics (Claudino et al., 2017; Sakurai et al., 2023). However, accurately estimating hGRF from vGRF remains challenging. This study aims to derive a regression equation for hGRF estimation based on vGRF measurements during CMJ.
Drawing insights from studies on ground reaction forces (Lombard et al., 2017), this study aims to estimate the hGRF (anterior-posterior) from vGRF. By delving into this regression analysis, our research seeks to contribute a refined understanding of jump biomechanics, facilitating practitioners in extracting comprehensive insights from standard jump-testing protocols.

METHODS: 40 Participants (n=40) from the All India University (AIU) Athletics Championship were asked to participate in this study. Each athlete performed 3 trials of countermovement jump with hands on the hip. The best of the three trials is considered for the study. Peak GRF at take-off force is taken in all three directions i.e., Vertical force and horizontal (anterior-posterior force & mediolateral force). For this study, only the anterior-posterior force is considered. The force data was measured through bilateral Kistler Force plate model 9287CA with dimensions 1200x600x100 and analyzed using MARS software.
Microsoft Excel was used to perform the statistical analysis. Pearson’s product-moment correlation was used to determine the relationship between the vGRF and hGRF. Multiple regression was used to determine the influence of selected independent variables on hGRF during the take-off. In all cases, an alpha level of 0.05 was used to determine statistical significance.

RESULTS: The Mean value of vGRF is 1696.61 N. The mean value of hGRF is 138.40 N (anterior-posterior) and 34.877 N (mediolateral). Table 1 shows the Median, standard error, and standard deviation values of all three GRFs.

Table 1: Descriptive Statistics.

	Mediolateral GRF [N] mGRF	*Anterior-posterior GRF [n] aGRF*	*Vertical GRF [n]*
Mean	34.88	138.40	1696.67
Standard Error	3.25	9.37	74.46
Median	29.59	122.67	1668.48
Standard Deviation	20.53	59.24	470.91

The correlation coefficient (r) was 0.6678 with p-value of 0.00001 for vGRF and anterior-posterior hGRF, while the r= 0.67 for vGRF and hGRF (mediolateral). Both the r values were statistically significant with p=0.00001 (<0.05). The statistical analysis shows that both hGRF has a strong correlation with vGRF as shown in table 2.

Table 2: Correlation Table.

	Mediolateral GRF [N]	*Anterior-posterior GRF [n]*	*p-value*
1. hGRF (ML) [N	1		
2. hGRF (AP) [n	0.62	1	0.00001
3. vGRF [n]	0.67*	0.67*	

*Significant relationship at α=0.05

Multiple regression analysis shows that the hGRF accounts for 49.96% of vGRF and is statistically significant. Table 3 shows the regression coefficient value (0.4996) and adjusted regression coefficient (0.4725).

Table 3: Regression Statistics

1. Multiple R	0.706
2. R Square	0.499
Adjusted R Square	0.472
Standard Error	43.019
Observations	40

DISCUSSION: The hGRF (anterior-posterior) force estimation from 1D force plate may not be as accurate as the direct measurement with a 3D force plate, it can still provide useful insights, especially in situations where 3D force plates are not available. This approach allows researchers and practitioners to glean information about AP forces from more accessible force measurement tools. 1D force plates measure forces along a single axis (typically vertical). The regression equation derived from 3D data might attempt to capture the relationship between vertical and horizontal forces, but the reduction to 1D necessarily simplifies the biomechanical model, potentially leading to a loss of accuracy.

While some studies explore methods to estimate horizontal forces from vertical force measurements, it's crucial to note that these methods often involve assumptions about the movement and may not be universally applicable. The accuracy of such calculations can vary based on factors such as jump technique, participant characteristics, and the specific algorithms used (Meylan et al., 2010; McMahon et al., 2018).

In practical applications, researchers often use 3D force plates to directly measure both vertical and horizontal ground reaction forces for more accurate biomechanical analyses. While attempts to estimate hGRF from vGRF can provide insights, caution should be exercised, and the limitations of such calculations should be acknowledged, considering the complexities of human movement dynamics. Estimating Anterior-Posterior Ground Reaction Force (AP GRF) from Vertical Ground Reaction Force (vGRF) in a 1D force plate (the most common and cost-effective alternative to 3D force plates) based on a derived regression equation from 3D force plate data involves certain assumptions and considerations. While this approach might offer insights, it's important to acknowledge potential limitations and challenges.

CONCLUSION: This study focused on predicting the horizontal GRF (anterior-posterior) from the vertical GRF during the countermovement jump. As we delve into deriving a regression equation for estimating hGRF from vGRF during CMJ, this research seeks to contribute a refined understanding of jump biomechanics, enabling practitioners to extract more comprehensive insights from standard jump-testing protocols.

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