BIOMECHANICAL ANALYSIS OF LOADED PLYOMETRIC EXERCISES

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INTRODUCTION: Plyometric training is effective, although there is considerable variation in program design (deVillarreal et al., 2009). To further understand elements of plyometric program design such as intensity and optimal exercise selection, kinetic variables of plyometrics have been assessed (Ebben et al., 2011, Kossow & Ebben, 2014). Research also shows that some plyometric exercises more closely approximate the horizontal and vertical forces and their ratio (H:V) that is present during sprint starts (Duffin et al., 2019).

Plyometric intensity has also been studied in loaded and unloaded conditions. This research includes assessment of exercises such as the loaded countermovement jump with 30% of the subject's back squat load (Ebben et al., 2011), the standing long jump with 1.5 kg or 3.0 kg dumbbells (Papadopoulos et al., 2011), and training with plyometrics loads that ranged from 2 kg to 12 kg (Rosas et al., 2016), 8% of body mass (Kobal et al., 2017), or weighted vests using 10-11% of body mass (Khlifa et al., 2010). No studies assessed the optimal external loads for a variety of plyometric exercises. Therefore, the purpose of this study was to assess several plyometric exercises and loading conditions, and the resultant multi-planar kinetic performance variables, for the purpose of quantifying exercise intensity and potential specificity to sprinting.

METHODS: Fifteen women (mean ± SD, age = 19.00 ± 0.94 yr) served as subjects and provided informed consent. The study was approved by the institution's Internal Review Board.

Subjects were tested during the standing long jump (SLJ), 18-inch hurdle hop (HH) (Figures 1-3), power skip (SKP), double leg hop (DLH), and countermovement jump (CMJ). Each plyometric exercise was performed in a body weight condition, as well as with handheld loads weighing 0.57, 1.13, 1.70, and 2.26 kilograms. Data were obtained from two flush to the floor-mounted force platform deployed in series (Accupower, Advanced Mechanical Technology, Inc., Watertown, MA, USA).

Peak ground reaction forces (GRF) for the frontal (F), horizontal anterior (H), and vertical (V) planes were obtained, and the H:V were calculated, for each plyometric exercises and load condition.

Data were analyzed with SPSS 27.0 using a two-way ANOVA with repeated measures for plyometric exercise and load. Bonferroni adjusted pairwise comparison were conducted when main effects were present. The reliability of the trials was assessed using intraclass correlation coefficients (ICC) for each of the dependent variables. Assumptions for linearity of statistics were tested and met. Statistical power (d) and effect size (η_p^2) are reported, and all data are expressed as means ± SD.

Figures 1-3. Hurdle Hop with load of 1.13 kg on force platforms.

RESULTS: The analysis of F GRF revealed significant main effects for plyometric type ($p = 0.004$, $d = 0.99$, $\eta_p^2 = 0.27$) but not for plyometric load ($p = 0.66$), or the interaction of plyometric load and type ($p = 0.84$). The analysis of H GRF revealed significant main effects for plyometric load ($p = .042$, $d = 0.71$, $\eta_p^2 = 0.16$) and plyometric type ($p \leq 0.001$, $d = 0.99$, $\eta_p^2 = 0.59$), but not the interaction of plyometric load and type ($p = .18$). The analysis of V GRF revealed significant main effects for plyometric load ($p \leq 0.001$, $d = 0.96$, $\eta p^2 = 0.27$) and plyometric type ($p \leq 0.001$, $d = 0.99$, $\eta_p^2 = 0.37$), but not the interaction of plyometric load and type ($p > 0.16$). The analysis of H:V revealed significant main effects for plyometric type ($p \leq 0.001$, $d = 0.99$, $\eta p^2 = 0.59$) but not for plyometric load ($p = 0.39$) or the interaction of plyometric load and type ($p = 0.24$). Figures 1-4 show the results of the analysis for the F GRF, H GRF, V GRF, and H:V. ICC for all data ranged from .70 to .99.

Figure 1. Frontal plane ground reaction forces (N) for each plyometric exercise and load condition.

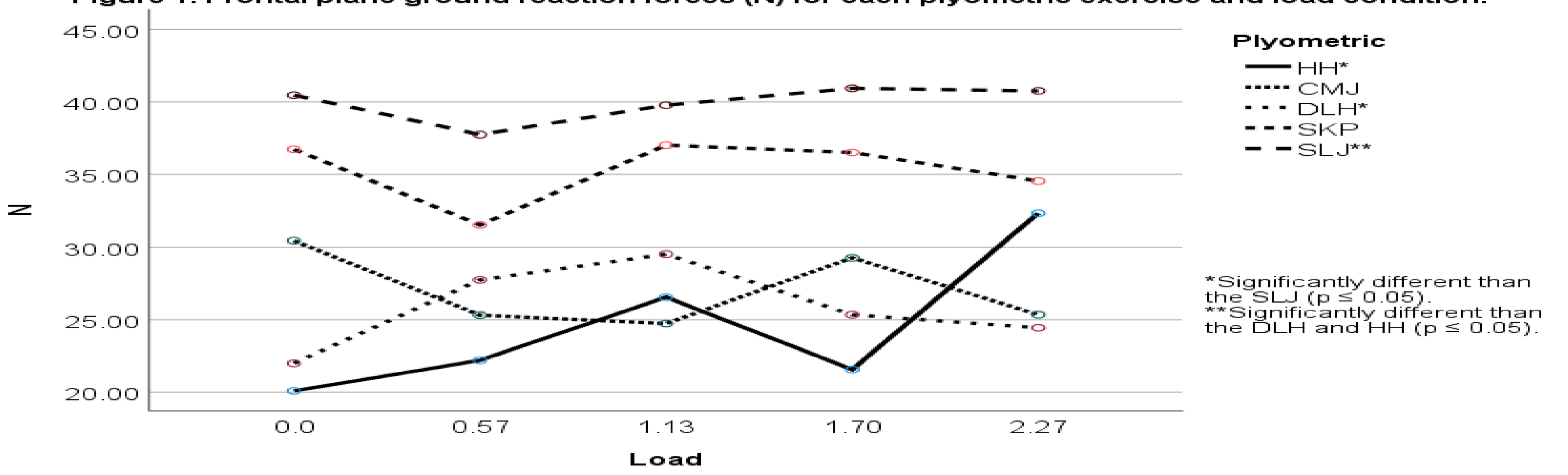


Figure 2. Horizontal (A-P) plane ground reaction force (N) for each plyometric exercise and load condition.

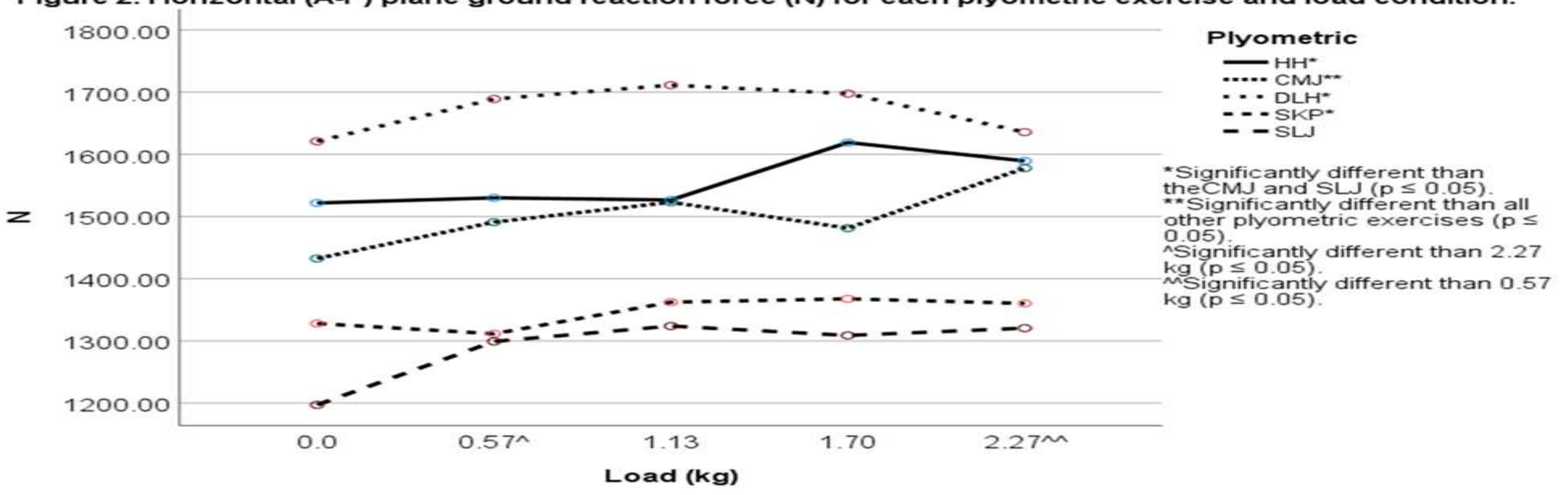


Figure 3. Vertical plane ground reaction forces (N) for each plyometric exericse and load condition.

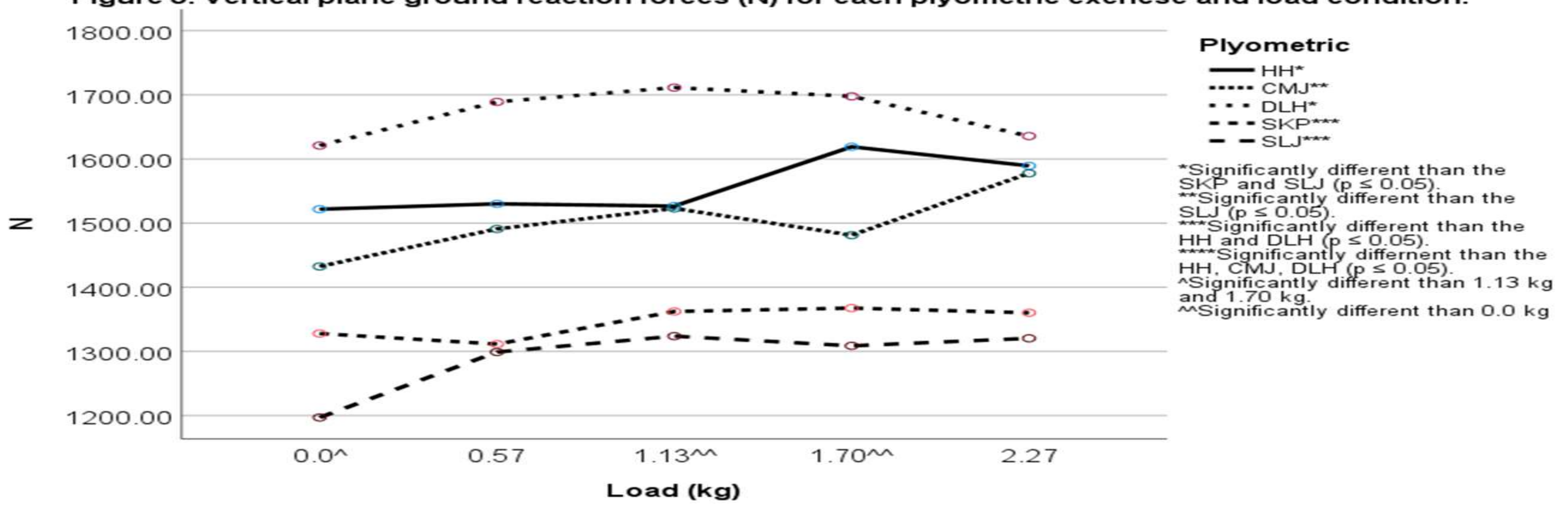
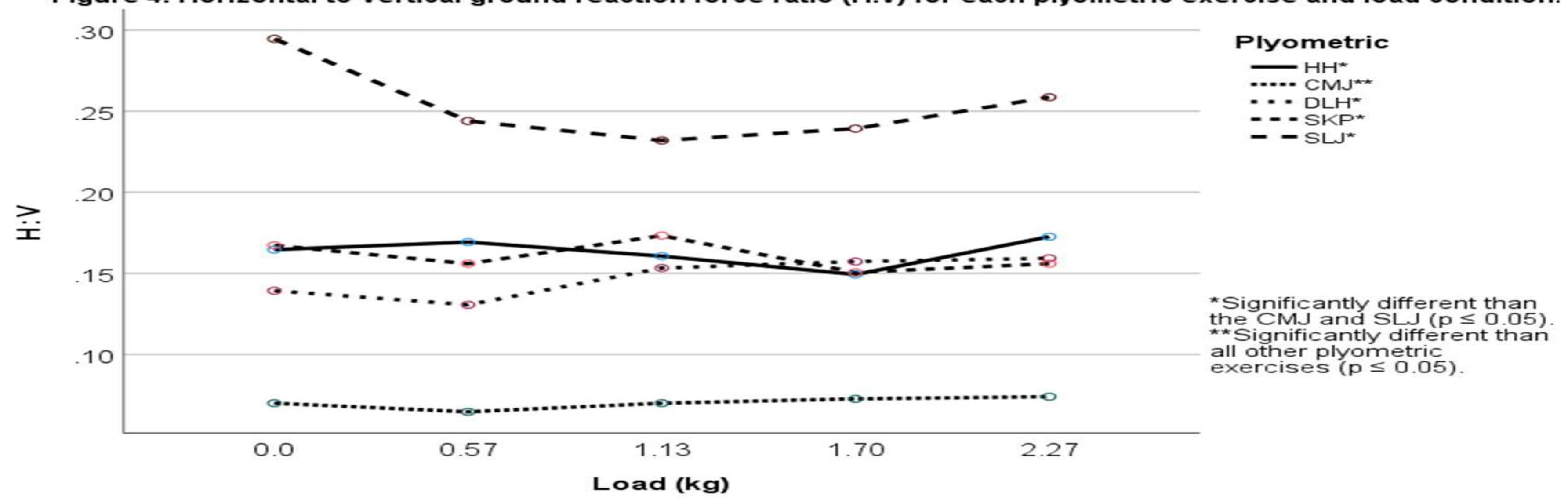


Figure 4. Horizontal to vertical ground reaction force ratio (H:V) for each plyometric exercise and load condition.



DISCUSSION/CONCLUSION: This is the first study to assess the kinetic features of a variety of plyometrics performed in a variety of load conditions and planes of motion. Results show that there are differences in GRF and H:V among these exercises for some of the variables assessed, and in some cases, the magnitude of added load effected the kinetics. Previous research assessing plyometrics using added loads examined only one exercise and one or two different loads. (Ebben et al., 2011; Papadopoulos et al., 2011).

The present study shows that the loads in the higher end of the range used were superior for some of the variables assessed, while the SLJ was optimal in the no load condition. Thus, training interventions should use the plyometrics and loads that optimize the exercise kinetics.

In the present study, the H:V was predictably lowest for the countermovement jump. The SLJ best approximates the H:V of standing sprint starts and sprinter position sprint starts, which were shown to have a H:V of .36 and .40, respectively (Duffin et al., 2019).

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