Are CrossFit® pull-ups riskier for shoulders? A biomechanical assessment of technique demands

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Summary

We collected and analyzed kinematics and kinetics of strict (SPU), kipping (KPU), and butterfly pull-ups (BPU) in experienced recreational CrossFit athletes using 3D optical motion tracking, force transducers, and musculoskeletal modeling. Each technique showed distinct demands: ranges of motion of glenohumeral (GH) flexion were highest in KPUs, and descent velocities were highest in BPUs. GH extensor and adductor moments were higher in SPUs and KPUs throughout a large part of the motion; but, at the lowest position, GH moments were highest in BPUs. Findings highlight the distinct demands and the importance of controlling the full range of motion to reduce injury risks.

Introduction

CrossFit is a mixed-modality sport that has gained popularity exponentially during the past two decades. Injury prevalence is estimated at 32.8%, and the shoulder is the most affected area, often during pull-up variations like KPU and BPU [1,2]. Unlike SPUs, these techniques use swinging motions from the lower body to create momentum, allowing athletes to perform faster and higher volume repetitions. However, their safety for amateur athletes is uncertain. Knowledge of their demands can help coaches create strategies to reduce injury risk. Joint angles and moments in the SPU have been reported [3,4] and discussed in terms of injury risk factors. The objective of this study was to analyze kinematics and kinetics in KPU and BPU techniques in addition to the SPU technique.

Methods

Nine experienced recreational CrossFit athletes performed sets of multiple SPUs, KPUs and BPUs. Data was recorded with optical motion tracking using a full-body marker set with detailed clavicle, scapula and humerus models. A pull-up rack was instrumented with handles fixed to 6-DOF force transducers. Experimental data was combined with a musculoskeletal model (OpenSim) [5] and inverse kinematics and inverse dynamics were performed. Differences between GH and scapulothoracic (ST) joint kinematics and joint moments among the different techniques were evaluated with repeated-measures statistical parametric mapping for the concentric (ascent) and eccentric (descent) phases.

Results and Discussion

Peak GH external rotation was similar across techniques. In SPUs and KPUs, this occurred at the highest position at zero velocity, and in BPUs, during descent, with the shoulder externally rotating while flexing and abducting – a position identified as a potential injury risk factor [3,6]. Peak GH flexion was highest in KPUs at the lowest position, coinciding with peak GH abduction. This position requires sufficient ST upward rotation to mitigate injury risks associated with reduced subacromial space [3,6], but less upward rotation was observed in KPUs than in the other techniques. GH angular velocities were higher in KPUs and BPUs (Figure 1). Peak GH extension and adduction velocities during the ascent phase were similar in KPUs and BPUs. However, GH flexion, abduction and internal rotation velocities during descent (eccentric) were significantly higher in BPUs – factors linked with overuse injuries. GH extensor and adductor moments were most prominent in KPUs and SPUs throughout a large part of the motion. However, at the end of the descent phase – when the shoulder moves to peak flexion and abduction – GH extensor and adductor moments were much larger in BPUs compared to the other techniques. High joint moments during eccentric contractions at large ranges of motion can become an injury risk factor in high-volume workouts.

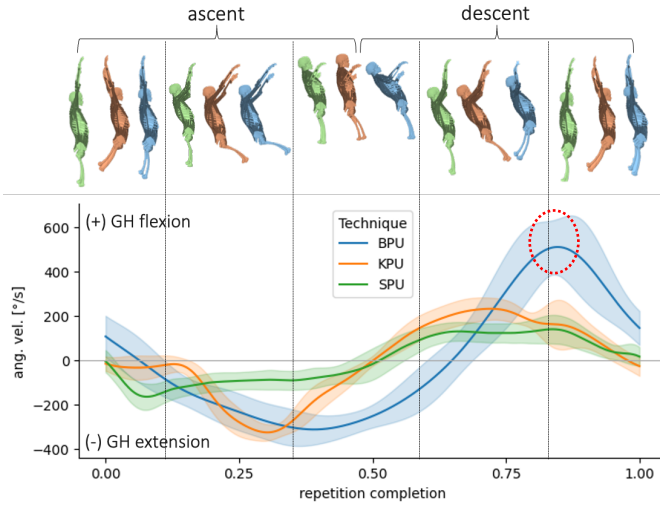

Figure 1: GH flexion(+)/extension(-) angular velocities displayed as mean and standard deviation across all repetitions and subjects. Red circle highlights the peak descent angular velocity of BPUs.

Conclusions

SPUs, KPUs, and BPUs impose distinct demands on shoulder movement ranges, angular velocities, and joint moments. To minimize injury risk, athletes must develop control over the complete range of motion and account for overuse risk factors.

References

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