Kinematic and muscle activation differences between a standard-pull up and a dynamic CrossFit “kipping” pull-up

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ABSTRACT

The standard pull-up (SPU) is an effective upper body resistance exercise used throughout the fitness community to build muscular strength. However, some athletes prefer activities that employ a wider range of muscles such as CrossFit which has become widely popular since the early 21st century. CrossFit introduced the kipping pull-up (KPU) which combines the SPU with a common move in gymnastics known as the "glide kip.” PURPOSE: The purpose was to compare overall EMG muscle activation, and kinematics between a SPU and a KPU. We hypothesized that the additional motion generated by the kipping action of the KPU would significantly reduce the muscle activation in the upper body muscles compared to the SPU, while increasing the activation of hip-flexor and abdominal muscles. METHODS: This study was a within-subject, randomized, counterbalanced design of 11 male subjects who actively participated in CrossFit and were familiar with both styles of pull-ups. They had a mean age of 30 years (±3.35) (mean ± SE). Electrodes were placed on the: infraspinatus (IF), latissimus dorsi (LD), rectus abdominis (RA), external oblique (EO), tensor fasciae latae (TFL), biceps brachii (BB), iliopsoas (IL), and pectoralis major (PM). Reflective markers to measure kinematics were placed on the subjects’ right side: 8th rib, greater trochanter, knee axis of rotation, and lateral malleolus. Subjects performed a set of 5 SPU and 5 KPU in random order, while kinematics and muscle activation were recorded. Data were analyzed with paired samples t-tests. RESULTS: The following kinematic variables were significantly greater in KPU compared to SPU: Max hip angle (48.81 ± 6.80°, p<.001), max knee angle (56.52 ± 11.26°, p=.001), hip range (24.18 ± 3.54 cm, p<.001), average angular hip velocity (76.81 ± 9.58°/s, p<.001), and average angular knee velocity (127.23 ± 35.06°/s, p=.005). These muscles showed significant reduction in muscle activation from SPU to KPU: LD (5.86 ± 6.21%, p=.046) and BB (13.58 ± 5.62%, p=.018). Whereas, these muscles showed significant increase in muscle activation from the SPU to KPU: RA (16.60 ± 3.55%, p<.001), EO (14.57 ± 7.33%, p=.001), TFL (16.24 ± 7.33%, p<.001), and IL (44.54 ± 31.64%, p=.001). CONCLUSION: It was concluded that there were significant increases in muscle activation in the hip flexor and abdominal muscles, which generated a significant ant/post swinging. The significant reduction in upper body muscle activation was likely due to this added movement. A KPU may be a better overall workout because it incorporates more muscles. Additionally, reduced upper body muscle activation could theoretically allow an individual to complete more repetitions with less fatigue.

INTRODUCTION

- The standard pull-up (SPU) is an effective upper body resistance exercise used throughout the fitness community to build muscular strength
- Some athletes prefer activities that engage a wide range of muscles and in a group setting such as CrossFit which has become widely popular since the early 21st century [4]
- CrossFit introduced the kipping pull-up (KPU) which combines the SPU with a common move in gymnastics known as the “glide kip” [5][10][17]
- **Purpose**: Compare overall EMG muscle activation and kinematics between a SPU and a KPU. A KPU combines the movement of a SPU with the swinging motion of a gymnastic “glide kip” to lift themselves over the bar. Different from the SPU, the KPU uses not only their upper body muscles, but also their lower body muscles (hip flexors) and abdominal muscles.
- **Hypothesis**: Additional momentum generated by the overall kipping motion of the KPU, would significantly (p<.05) reduce the total average muscle activation in the upper body muscles associated with the SPU, while increasing activation of hip-flexor and abdominal muscles

Figure 1: Muscle electrode placement

METHODS

- **Subject/Design**: Within subject, randomized, counterbalanced design of male subjects (n=11) who participated in CrossFit for a minimum of three months.
  - *Anthropometrics*: (Mean ± SE): age of 30 ± 3.5 yrs, height of 178.8 ± 1.6 cm, weight of 85.0 ± 3.1 kg, and body fat percentage of 12.5 ± 2.0 %
- **Procedure/Materials**: Participants came for a total of two sessions (T1 & T2)
- T1: Evaluated KPU and SPU form, anthropometrics measured, and familiarization of procedure for T2
- T2: Electrode and Marker placement, and max voluntary isometric contraction (MVIC) completed [7]. Subjects completed two trials of pull-ups: 5 SPU’s and 5 KPU’s

- **Data Analysis**: *Electromyography*
- Electrodes were placed on 8 muscles on the left side of their bodies: infraspinatus (IF), latissimus dorsi (LD), rectus abdominis (RA), external oblique (EO), tensor fasciae latae (TFL), biceps brachii (BB), iliopsoas (IL), and pectoralis major (PM) (Figure 1).
- Mean muscle activation of each individual muscle during the middle three pull-ups were analyzed
- Muscle activation represented as %MVIC

- **Data Analysis**: *Kinematics*
- 2D markers placed on the right side of the body on: 8th rib, greater trochanter of the femur, knee axis of rotation, and lateral malleolus of the fibula
- Max hip and knee angle, hip and knee movement traveled in the ant/post direction, and mean hip and knee angular velocity were measured and averaged for the three middle pull-ups (Figures 2 and 3).

Figures 2 and 3: Motion tracker path of markers for a KPU (left image) and SPU (right image) for Subject 1

RESULTS

- All kinematic variables evaluated during the study are presented in Table 1, comparing a single SPU and KPU. All KPU kinematic variables (accept range of the knee) were significantly different from SPU variables. This was a quantitative indication that there were significantly different movement patterns between the two different pull-ups.

Table 1. Differences between SPU and KPU kinematic variables. *Indicates significant difference between SPU and KPU (p<.05), **Indicates significant difference between SPU and KPU (p<.001). Negative value indicates KPU>SPU

Kinematic Variable	SPU-KPU	p-value
Max Hip Angle	-48.81 ± 6.80	<.001**
Max Knee Angle	-56.52 ± 11.26	.001*
Range $Hip_{ant/post}$	-24.18 ± 3.54	<.001**
Range $Knee_{ant/post}$	-8.22 ± 4.75	.114
Mean Hip Angular Velocity	-76.81 ± 9.58	<.001**
Mean Knee Angular Velocity	-127.23 ± 35.06	.005*

- Hip and knee angles were greater in a KPU when compared to a SPU (Figures 4 and 5). Subject 1 demonstrated this general trend and was representative of the findings for all subjects

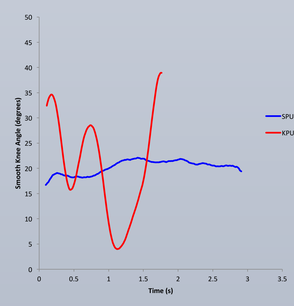

Figure 4. Knee Angle vs. Time during a single SPU and KPU for Subject 1.

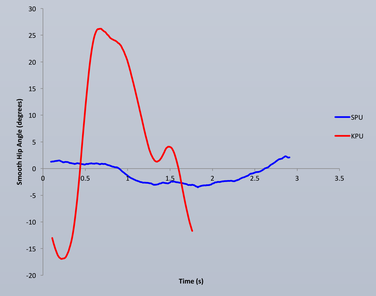

Figure 5. Hip Angle vs. Time during a single SPU and KPU for Subject 1.

- Full SPUs and KPUs were compared in Figure 6 and 7 between all recorded upper and lower body muscles. All lower body muscles had significantly higher activation during the KPU than the SPU. The increase in lower body activation in the KPU vs the SPU was offset by the significant decrease in some upper body activation in the upper body muscles in the KPU vs. SPU.

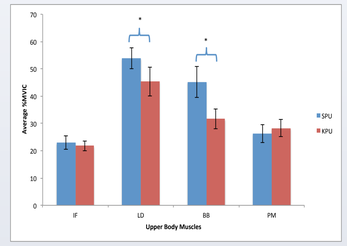

Figure 6. (Mean ± SE) Average percent maximum voluntary isometric contraction (%MVIC) throughout a full SPU and KPU for the infraspinatus (IF), lattisimus dorsi (LD), biceps brachii (BB), and pectoralis major (PM). *Indicates significant difference between SPU and KPU (P<.05), **Indicates significant difference between SPU and KPU (P<.001).

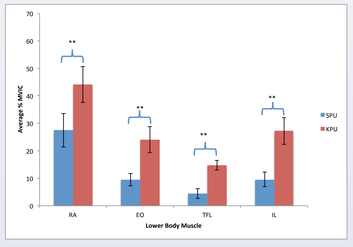

Figure 7. (Mean ± SE) Average percent maximum voluntary isometric contraction (%MVIC) throughout a full SPU and KPU for the rectus abdominis (RA), external oblique (EO), tensor fasciae latae (TFL), and iliopsoas (IL). *Indicates significant difference between SPU and KPU (P<.05), **Indicates significant difference between SPU and KPU (P<.001).

DISCUSSION

- From Table 1 we were able to conclude that kinematically, these are two different pull-ups, because the KPU utilizes a more dynamic motion than the SPU.
- This difference is characterized by a substantial sway in the sagittal plane for a KPU, and minimal movement in the ant/post direction for a SPU.
- An important factor causing differences in a KPU was the hip angular velocity (p < .001) because it represents that there was a distinct kinematic difference in form between a KPU and SPU.
- Based off previous literature, it was found that hip flexion was the major action of the IL and TFL [5][9], and the EO and RA were significant contributors to the motion of the glide kip [11]. The significant activation of these lower body muscles may explain/compensate for the lack of upper body muscle activation in a KPU when compared to a SPU, so the individual can still raise themselves to the bar.
- LD and BB had significantly lower muscle activation during a KPU than a SPU (Figure 6).
- All four lower body muscles (RA, EO, TFL, and IL) had significantly higher muscle activation during a KPU than a SPU
- The KPU is likely a better full-body workout than the SPU for two reasons:
  - Reduction in upper body muscle activation could slow down fatigue, allowing an athlete to perform more pull-ups in one set
  - The KPU utilizes a wider range of muscles than the SPU, contributing to a more encompassing workout.
- Further studies should explore the effect of a KPU on muscular fatigue when compared to a SPU, as well as other physiological phenomena associated with the KPU.

CONCLUSION

There were significant increases in muscle activation in the hip flexor and abdominal muscles, which generated a significant anterior/posterior swing. The significant reduction in upper body muscle activation was likely due to this added motion. A KPU may be a better overall workout because it incorporates more muscles. Additionally, reduced upper body muscle activation could theoretically allow an individual to complete more repetitions with less fatigue.

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