A comparison of muscle activity between strict, kipping and butterfly pull-ups

Toby Williamson¹ *, Phil Price¹

¹Faculty of Sport, Allied Health, and Performance Science, St Mary’s University, UK

ARTICLE INFO
Received: 18.09.2020
Accepted: 18.02.2021
Online: 08.03.2021

ABSTRACT
The kipping pull-up (KPU) and butterfly pull-up (BPU) are variations of the strict pull-up (SPU) where an athlete uses hollow and arched body positions to gain momentum, before accelerating vertically. Understanding the muscle activity of each of these exercises will help coaches better utilise them within a strength and conditioning programme. The aim of this study was to compare upper and lower body muscle activation between the SPU, KPU and BPU during the concentric and eccentric phases of each exercise. 11 participants had surface electromyography data collected from three upper and three lower body muscles while completing each pull-up variation. Peak EMG data from each phase for each muscle from the SPU were used to normalise peak KPU and BPU EMG data. A repeated measures ANOVA with Bonferroni post hoc testing was used to identify significant differences between each variation. The results show significantly reduced muscle activation in the bicep brachii during the concentric (p < 0.05; d = 1.1) and eccentric (p < 0.05; d = 1.1) phases of the BPU, when compared to the SPU. Activation of the latissimus dorsi was significantly lower during the concentric phase of the KPU (p < 0.02; d = 1.2) and eccentric phase (p < 0.01; d = 1.4) of the BPU in comparison to the SPU. Furthermore, significantly greater muscle activation was shown in the rectus femoris, gluteus maximus and rectus abdominus in both the KPU and BPU, when compared to the SPU. However, results differed within the concentric and eccentric phases. These findings show that both styles of kipping increase lower body muscle activation and decrease upper body activation in comparison to the SPU. Further, due to the different style of kip, the KPU and BPU display different muscle activations during both the concentric and eccentric phases.

Keywords:
Kipping pull-up
Butterfly pull-up
EMG

1. Introduction
The strict pull-up (SPU) is a popular exercise in many strength and conditioning programmes (Pate, Burgess, Woods, Ross, & Baumgartner, 1993; Woods, Pate, & Burgess, 1992). The pull-up requires the upper limbs to pull the body (which is in a hanging position while gripping onto a fixed bar) vertically until the chin passes the bar (Ronai & Scibek, 2014; Youdas et al., 2010). The biceps brachii (BB) and latissimus dorsi (LD) are the prime movers of the SPU exercise as the glenohumeral joint and elbow joint go through extension and flexion during the concentric phase, respectively, and are considerably more active during the pulling (concentric) and lowering (eccentric) phase of the SPU than other upper body musculature (Dorma, Deakin, & Ness, 2013). Interestingly, Dickie, Faulknor, Barnes and Lark (2017) highlighted that differences in upper body muscle activation are seen when comparing the concentric and eccentric phases of the SPU. Further, changes in approach to performing the SPU exercise has seen changes in muscle activation. In 2010, Youdas et al. examined the effect of hand orientations on muscle activity in seven upper body muscles and found the BB produced higher levels of muscle activity when a supinated grip was used compared to a pronated grip. These studies suggest muscle force contributions to the SPU exercise can differ depending on the phase of the exercise and the approach used.

The kipping pull-up (KPU) is a variation of the SPU, where the lower limbs are incorporated to create a greater impulse via an increase in force over a longer duration. This increase in impulse causes greater momentum and velocity during the concentric phase of the exercise. KPU’s have recently gained popularity in physical training communities as they allow more reps to be completed in a shorter amount of time, and can be performed by...
athletes who may not have the upper body strength to perform
SPU’s. KPs have been compared to a glide kip in gymnastics
(Yamasaki, Gotoh, & Xin, 2010), this is largely due to increased
contribution of the lower body, when compared to the SPU
(Dinunzio, Porter, Van Scoy, Cordice, & McCulloch, 2018). As a
result, upper body muscle contributions have been reported to be
reduced in the KPU (Snarr, Hallmark, Casey, Nickerson, & Esco,
2015). Snarr and colleagues (2018) reported a decrease in both BB
and LD muscle activation during the KPU when compared to the
SPU, suggesting an increased emphasis of hip extension to be a
possible cause. Dinunzio et al. (2018) provide support for these
claims as they reported increased lower limb joint angles and
increased lower limb muscle activation.

Similar to the KPU, another variation of the SPU which has
also gained recent popularity is the butterfly pull-up (BPU). The
BPU requires an advanced form of kipping, where the athlete
performs a more cyclical style of kipping in comparison to the up
and back motion used for the KPU. The BPU style of kipping can
be performed more quickly, though requires greater whole-body
coordination to perform. Because of the involvement of the lower
body, it is logical to assume upper body muscle activations during
the BPU would also be lower in comparison to the SPU. Further,
due to the different kipping strategy, there may be different
muscle activation patterns between the KPU and BPU. However,
no research has currently investigated the BPU.

The programming of these pull-up variations has often been
based on the different adaptations they may develop. Typically,
the SPU has been programmed for developing upper body weight-
relative muscular strength (Pate et al., 1993) and testing upper
body muscular endurance (Ronai & Scibek, 2014), whereas the
KPU and BPU are often programmed to improve whole body
coordination and for increasing the number of repetitions the
athlete can perform. However, little is known regarding the
muscular strategies needed to perform the KPU and BPU. This
knowledge will provide greater understanding of how these
exercises effect key physiological adaptations, such as maximal
strength, muscular endurance and hypertrophy, enabling coaches
and rehabilitators to make better programming decisions. It is
therefore the aim of this study to compare upper and lower body
muscle activation between the SPU, KPU and BPU during both
the concentric and eccentric phases of the exercise. It is
hypothesised that upper body muscle activation will be higher in
the SPU, lower body muscle activation will be higher in the KPU
and BPU, and the KPU and BPU will display different lower body
muscle activations throughout the exercise.

2. Methods

2.1. Participants

Ten males (height = 176.6 ± 9.1 cm, weight = 84.9 ± 6.5 kg, age
= 33 ± 6 years) and one female (height = 155 cm, weight = 54.9
kg, age = 31 years) volunteered for the study after being
recommended by the head coach of a CrossFit affiliate. The
inclusion criteria required participants to be injury free, capable
of performing five repetitions of each pull-up variation
(competency determined by the head coach) and have a minimum
of twelve months experience training at the Crossfit affiliate. Prior
to the study, participants provided written, informed consent. The
study was approved by the St Mary’s University Ethics
Committee.

2.2. Procedures

Participants took part in one testing session which was preceded
by 48 hours total rest. Before the trial commenced, height (SECA
Free Standing Height Measure) and weight (Marsden Weighing
Group Portable Scale) were measured. A 10-minute
familiarisation of the equipment and procedures was completed
before two rounds of a standardised warm up were performed: 250
m row, ten PVC pipe pass throughs, eight kettlebell swings and
six banded reverse rows. Following the warm-up, participants
completed five repetitions of all three pull-up variations in
random order. Each set was followed by 5 minutes rest. Due to its
ability to show high muscle activation in a pull-up, a proned,
medium width grip (1.5 times bi-acromial distance) was used for
all three variations (Andersen, Finland, Wiik, Skoglund, &
Saeterbakken, 2014). The use of chalk or gymnastic handguards
was not permitted. The SPU started in a hanging position with the
arms fully extended and feet off the floor. Participants then pulled
themselves upward, using only their upper body and without the
use of the lower limbs to generate momentum. The top of the
repetition was completed when the chin successfully passed over
the horizontal line of the bar, before returning to the start point.
For the KPU, participants started in the same hanging position
(Figure 1a). From the start position they would pull forward with
an arched body (extension of the spine and hips – Figure 1b), then
back to a hollow position (flexion of the hips – Figure 1c) to
generate momentum, before swinging themselves upward with
the chin passing over the horizontal line of the bar (Figure 1d).
During the descent, they would push backwards and fall down
into the hollow position (Figure 1e), before passing though the
start point as they completed the next repetition.

Figure 1: The phases of the kipping pull-up

T. Williamson and P. Price / The Journal of Sport and Exercise Science, Journal Vol. 5, Issue 2, 149-155 (2021)
The BPU also started in the hanging position (Figure 2a). The participant would move into the hollow body shape (Figure 2b) to generate momentum and dynamically pull up to the line of the bar (Figure 2c). On their descent they would pull into the arch position (Figure 2d), before once again passing through the start point (Figure 2e & 2f).

Figure 2: The phases of the butterfly pull-up

A video camera (Panasonic HC-V210 HD camcorder, Panasonic UK Ltd., Berkshire, UK) recording at 50 Hz was placed four metres behind the participant in the frontal plane. The height of the camera was set so that a reflective marker placed on the 7th vertebrae of the cervical portion of the spine was as central as possible when in the hanging start position. The marker was used to identify the concentric and eccentric phases of each exercise. The concentric phase was deemed to have started as soon as the arms were fully extended when descending from the previous repetition with the marker being at its lowest position. The start of the eccentric phase was identified as the moment the athlete began their descent from the peak height achieved when the marker was at its highest position. These kinematic data were analysed using Kinovea analysis software (Kinovea 0.8.15, Kinovea open source, www.kinovea.com).

2.3. Electromyographical Measurement

Electromyographical (EMG) data was recorded using a Delsys Myomonitor® IV Wireless Transmission & Datalogging System (Delsys Inc. Boston, MA, USA) at 1000 Hz. Prior to the application of electrodes, participant’s skin was shaved and swabbed. Electrodes were placed on the muscle belly in three upper and three lower body locations, on the participant’s dominant side, in line with the muscle fibres. Electrode location followed previous recommendations, which can be seen in Table 1 (Criswell, 2010; Hermens et al., 1999). However, deviation was permitted at the discretion of the lead researcher, when visual identification of the muscle belly differed from recommendations. For example, the muscle belly of the rectus abdominus would often vary between participants in both distance from the xiphoid process and alignment between the linear alba and ribs.

Table 1: Shows electrode location for each muscle and the literature used to identify correct application

| Muscle               | Electrode location                                                                 | Reference                       |
|----------------------|-------------------------------------------------------------------------------------|---------------------------------|
| Bicep brachii (BB)   | Centre of flexed bicep. 60% of the distance from the fossa cubit and medial acromion. | Hermens et al. (1999)           |
| Latissimus dorsi (LD)| 4 cm inferior to the angle of the scapula. 50% of the distance from the vertebrae and the lateral border of the latissimus dorsi. | Criswell (2010)                 |
| Infraspinatus (IF)   | 4 cm inferior to the spine of the scapula, in the middle of the fossa.             | Criswell (2010)                 |
| Rectus femoris (RF)  | 50% of the distance from the anterior superior iliac crest to the superior part of the patella. | Hermens et al. (1999)           |
| Gluteus maximus (GM) | 50% of the distance from the sacrum to the greater trochanter. In correspondence with the greatest prominence of the buttock. | Hermens et al. (1999)           |
| Rectus abdominus (RA)| 50% of the distance from the xiphoid process to the naval. 50% of the distance from the linear alba to the ribs. | Hermens et al. (1999)           |
2.4. Statistical Approach

EMG readings from repetitions 2-4 were collected in order to eliminate any changes in activation and movement pattern during the swing start of the KPU and BPU (Dinunzio et al., 2018). EMG data for each muscle was individually rectified and smoothed using a 101-point rolling average. The timeframe at which EMG recording began was then identified within the video footage in order to synchronise data sets and define the concentric and eccentric phases of each rep. From here, the peak EMG activations for each phase of all three repetitions where identified and averaged (EMGPEAK). This provided an EMGPEAK for each muscle, across each phase, for all three pull-up variations. Data from the SPU was used to normalise KPU and BPU data (Sousa & Tavares, 2012). EMGPEAK values were presented as a percentage of peak SPU muscle activation, with peak SPU muscle activation displayed at 100%. EMGPEAK values were screened for normality using the Shapiro-Wilk’s test identified that the following variables were non-normally distributed. RF and GM for the concentric phase, and BB, RF, GM, RA for the eccentric phase. The appropriate non-parametric statistical tests were therefore used on these data. Differences in peak muscle activations were shown for both the concentric and eccentric phases of each pull-up variation (Figures 3 to 8). Significant differences in EMGPEAK for the RF (Figure 3) were seen during both the concentric ($X^2 = 16.55, p < 0.01$) and eccentric phase ($X^2 = 20.00, p < 0.01$). EMGPEAK for the RF was significantly higher in the KPU concentric phase ($Z = -2.93, p < 0.01; d = 1.2$) and eccentric phase ($Z = -2.93, p < 0.01; d = 1.3$) in comparison to SPU. RF EMGPEAK was also significantly higher in the BPU in both the concentric phase ($Z = -2.93, p < 0.01; d = 1.4$) and eccentric phase ($Z = -2.93, p < 0.01; d = 1.3$) in comparison to SPU. EMGPEAK for the RF for the BPU was significantly higher than the KPU only during the eccentric phase ($Z = -2.93, p < 0.01; d = 1.1$).

For the BB, significant differences in EMGPEAK during the concentric phase were reported ($F(1.29, 12.95) = 4.23, p < 0.05$). Post hoc tests revealed BB EMGPEAK was only lower during the BPU ($p < 0.05; d = 1.1$) in comparison to SPU. Significant differences in BB EMGPEAK during the eccentric phase ($X^2 = 16.55, p < 0.01$) were also reported. EMGPEAK of the KPU was significantly lower than the SPU ($Z = -2.66, p < 0.01; d = 1.3$) and the BPU ($Z = -2.93, p < 0.01; d = 1.3$). These EMGPEAK differences can be seen in Figure 4.

Significant differences were highlighted for RA EMGPEAK (Figure 5) between pull-up variations during both the concentric phase ($F(1.94, 19.39) = 6.36, p < 0.05$) and eccentric phase ($X^2 = 14.36, p < 0.01$). Post hoc testing for the concentric data found the KPU to have significantly greater EMGPEAK ($p = 0.01; d = 1.3$) in comparison to SPU. Post hoc testing for the eccentric phase showed a lower EMGPEAK for the SPU ($Z = -2.93, p < 0.01; d = 1.6$) and KPU ($Z = -2.85, p < 0.01; d = 1.2$) when compared to that of the BPU.

3. Results

The Shapiro-Wilk’s test identified that the following variables were non-normally distributed. RF and GM for the concentric phase, and BB, RF, GM, RA for the eccentric phase. The appropriate non-parametric statistical tests were therefore used on

![Figure 3: EMGPEAK as % SPU for the rectus femoris across all three variations. Values are given as mean ± SD. * indicates significant difference ($p < 0.05$).](image)

![Figure 4: EMGPEAK as % SPU for the bicep brachii across all three variations. Values are given as mean ± SD. * indicates significant difference ($p < 0.05$).](image)
Figure 5: EMGPEAK as % SPU for the rectus abdominus across all three variations. Values are given as mean ± SD. * indicates significant difference ($p < 0.05$).

Figure 6: EMGPEAK as % SPU for the gluteus maximus across all three variations. Values are given as mean ± SD. * indicates significant difference ($p < 0.05$).

Significant differences in EMGPEAK for the GM were also reported between pull-up variations during both concentric ($X^2 = 13.27, p < 0.01$) and eccentric phases ($X^2 = 20.18, p < 0.01$) (Figure 6). GM EMGPEAK was significantly greater during the concentric phase for both the KPU ($Z = -2.85, p < 0.01; d = 0.8$) and BPU ($Z = -2.40, p < 0.05; d = 0.9$) in comparison to the SPU. Similarly, GM EMGPEAK was significantly greater for the KPU ($Z = -2.76, p < 0.01; d = 0.8$) and BPU ($Z = -2.93, p < 0.01; d = 0.9$) in comparison to the SPU during the eccentric phase.

Significant differences were also reported for LD EMGPEAK during both the concentric ($F(1.92, 19.16) = 5.55, p < 0.05$) and eccentric phase ($F(1.79, 17.90) = 14.73, p < 0.01$). LD EMGPEAK for the KPU was significantly lower ($p < 0.05; d = 1.2$) in comparison to the SPU during the concentric phase. For the eccentric phase LD EMGPEAK for the SPU was greater than both the KPU ($p < 0.01; d = 1.5$) and the BPU ($p < 0.01; d = 1.4$).

No significant differences were found for IF EMGPEAK during the concentric phase ($F(1.72, 17.17) = 2.27, p = 0.14$). However, a significant difference in IF EMGPEAK during the eccentric phase was reported ($F(1.96, 19.85) = 8.20, p < 0.01$). IF EMGPEAK for the BPU was significantly higher in comparison both to the KPU ($p < 0.05; d = 0.9$) and SPU ($p < 0.05; d = 1.2$). No other significant differences were found.

Figure 7: EMGPEAK as % SPU for the latissimus dorsi across all three variations. Values are given as mean ± SD. * indicates significant difference ($p < 0.05$).

Figure 8: EMGPEAK as % SPU for the infraspinatus across all three variations. Values are given as mean ± SD. * indicates significant difference ($p < 0.05$).
4. Discussion

The purpose of this study was to provide insight into the KPU and BPU in comparison to the SPU. Previous research has shown lower levels of upper body muscle activation in the KPU (Dinunzio et al., 2017; 2018) in comparison to the SPU. However, no research in this area exists for BPs and it is unknown how muscle activation may differ between the concentric and eccentric phases during all three pull-up variations. The results of this study confirm that both styles of kipping increase lower body muscle activation and decrease upper body activation in comparison to the SPU. It is important to point out that muscle activation was compared to levels shown in the SPU and not a true lower body MVC. Therefore, it is not possible to determine whether a true meaningful stimulus was produced in the lower body. Our findings also suggest that, due to the different style of kip, both the KPU and BPU display different muscle activations. Furthermore, these muscle activation patterns are dependent on the phase of the pull-up. This confirms the hypothesis of this study.

Confirming the findings from Snarr et al. (2018) an increase in lower body muscle activation was found in this study between the KPU and BPU in comparison to the SPU. While significant increases in muscle activation were found in all three lower body muscles, only the RF had elevated levels of activation across both phases in both the KPU and BPU. This increase in activation of the RF is expected, due to the lower body swing when moving between the hollow and arch position (Figure 1b-d and Figure 2b-e) in each style of pull-up. Similar findings were found by Dinunzio et al. (2018) who found the tensor fasciae latae (TFL) and iliopsoas (IL) muscles elicited greater levels of muscle activation during a KPU in comparison to the SPU. As the TFL, IL, and RF all contribute to flexion of the hip (Jiroumaru, Kurihara, & Isaka, 2014), this confirms the role of the hip flexors in generating momentum during the KPU and BPU.

As hypothesized, when absolute load (in this case body mass) is constant, the generation of momentum from the lower limbs during the BPU and KPU resulted in reduced upper limb muscle activation in comparison to the SPU. Both the BB and LD showed significant decreases in muscle activation during the BPU and KPU, though no differences in muscle activation were found between exercises for the IF. These findings compare with previous research done by Dinunzio et al. (2017) who presented absolute values with SPU data being subtracted from the KPU and then expressed as a % MVC. Therefore, the method in which muscle activation is presented differs between studies, which makes the comparison of findings difficult. No kinematic data was recorded in the sagittal plane for this study. As a result, differences in the arched and hollow body positions used in both the KPU and BPU in this study are not objectively known. Further, the participants were allowed to perform all three exercises at a self-selected speed. Participants being able to get into a greater arched position at a greater speed may increase the activation of certain muscles and influence the results of this study. To minimise this, we recruited participants with a similar training history with all three exercises. However, having this additional kinematic data would help provide insight to the muscle activation patterns when performing these exercises and further understand the differences between the KPU and BPU.

The purpose of this study was to provide insight into the KPU and BPU in comparison to the SPU. Previous research has shown lower levels of upper body muscle activation in the KPU (Dinunzio et al., 2017; 2018) in comparison to the SPU. However, no research in this area exists for BPs and it is unknown how muscle activation may differ between the concentric and eccentric phases during all three pull-up variations. The results of this study confirm that both styles of kipping increase lower body muscle activation and decrease upper body activation in comparison to the SPU. It is important to point out that muscle activation was compared to levels shown in the SPU and not a true lower body MVC. Therefore, it is not possible to determine whether a true meaningful stimulus was produced in the lower body. Our findings also suggest that, due to the different style of kip, both the KPU and BPU display different muscle activations. Furthermore, these muscle activation patterns are dependent on the phase of the pull-up. This confirms the hypothesis of this study.

Confirming the findings from Snarr et al. (2018) an increase in lower body muscle activation was found in this study between the KPU and BPU in comparison to the SPU. While significant increases in muscle activation were found in all three lower body muscles, only the RF had elevated levels of activation across both phases in both the KPU and BPU. This increase in activation of the RF is expected, due to the lower body swing when moving between the hollow and arch position (Figure 1b-d and Figure 2b-e) in each style of pull-up. Similar findings were found by Dinunzio et al. (2018) who found the tensor fasciae latae (TFL) and iliopsoas (IL) muscles elicited greater levels of muscle activation during a KPU in comparison to the SPU. As the TFL, IL, and RF all contribute to flexion of the hip (Jiroumaru, Kurihara, & Isaka, 2014), this confirms the role of the hip flexors in generating momentum during the KPU and BPU.

As hypothesized, when absolute load (in this case body mass) is constant, the generation of momentum from the lower limbs during the BPU and KPU resulted in reduced upper limb muscle activation in comparison to the SPU. Both the BB and LD showed significant decreases in muscle activation during the BPU and KPU, though no differences in muscle activation were found between exercises for the IF. These findings compare with previous research done by Dinunzio et al. (2017) who presented absolute values with SPU data being subtracted from the KPU and then expressed as a % MVC. Therefore, the method in which muscle activation is presented differs between studies, which makes the comparison of findings difficult. No kinematic data was recorded in the sagittal plane for this study. As a result, differences in the arched and hollow body positions used in both the KPU and BPU in this study are not objectively known. Further, the participants were allowed to perform all three exercises at a self-selected speed. Participants being able to get into a greater arched position at a greater speed may increase the activation of certain muscles and influence the results of this study. To minimise this, we recruited participants with a similar training history with all three exercises. However, having this additional kinematic data would help provide insight to the muscle activation patterns when performing these exercises and further understand the differences between the KPU and BPU.

The authors declare no conflict of interests.

References

Andersen, V., Finland, M. S., Wiik, E., Skoglund, A., & Saeterbakken, A. H. (2014). Effects of grip width on muscle strength and activation in the lat pull-down. The Journal of Strength & Conditioning Research, 28, 1135-1142.

Criswell, E. (2010). Cram’s introduction to surface electromyography. Sudbury, MA: Jones & Bartlett Publishers.

Dickie, J. A., Faulkner, J. A., Barnes, M. J., & Lark, S. D. (2017). Electromyographic analysis of muscle activation during pull-
up variations. *Journal of Electromyography and Kinesiology*, 32, 30-36.

Dinunzio, C., Porter, N., Van Scoy, J., Cordice, D., & McCulloch, R. S. (2018). Alterations in kinematics and muscle activation patterns with the addition of a kipping action during a pull-up activity. *Sports Biomechanics*, 18(6), 622-635.

Dinunzio, C., Van Scoy, J., Porter, N., Cordice, D., & McCulloch, R. S. (2017). Kinematic and muscle activation differences between a standard pull-up and a dynamic crossfit “kipping” pull-up. *International Journal of Exercise Science: Conference Proceedings*, 8(5), 61. https://digitalcommons.wku.edu/ijesab/vol8/iss5/61

Doma, K., Deakin, G. B., & Ness, K. F. (2013). Kinematic and electromyographic comparisons between chin-ups and lat-pull down exercises. *Sports Biomechanics*, 12, 302-313.

Hermens, H. J., Freriks, B., Merletti, R., Stegeman, D., Blok, J., Rau, G., Desselhorst-Klug, C., & Hägg, G. (1999). European recommendations for surface electromyography. *Roessingh Research and Development*, 8, 13-54.

Jiroumaru, T., Kurihara, T., & Isaka, T. (2014). Measurement of muscle length-related electromyography activity of the hip flexor muscles to determine individual muscle contributions to the hip flexion torque. *SpringerPlus*, 3, 624. https://doi.org/10.1186/2193-1801-3-624

Pate, R. R., Burgess, M. L., Woods, J. A., Ross, J. G., & Baumgartner, T. (1993). Validity of field tests of upper body muscular strength. *Research Quarterly for Exercise and Sport*, 64, 17-24.

Ronai, P., & Seibek, E. (2014). The pull-up. *Strength & Conditioning Journal*, 36, 88-90.

Snarr, R. L., Hallmark, A. V., Casey, J. C., Nickerson, B. S., & Esco, M. R. (2015). Electromyographic comparison of pull-up variations (Conference presentation). National Strength & Conditioning Association Conference, Orlando, 2015. Orlando, FL.

Snarr, R. L., Hallmark, A. V., Casey, J. C., Nickerson, B. S., & Esco, M. R. (2018). Electromyographic comparison of pull-up variations. *Journal of Australian Strength & Conditioning*, 26, 28-34.

Sousa, A., & Tavares, J. (2012). Repositório Aberto da Universidade do Porto: Surface electromyographic amplitude normalization methods: a review. Repositório Aberto Da Universidade Do Porto. Retrieved from: https://repositorio-aberto.up.pt/handle/10216/64430

Woods, J. A., Pate, R. R., & Burgess, M. L. (1992). Correlates to performance on field tests of muscular strength. *Pediatric Exercise Science*, 4, 302-311.

Yamasaki, T., Gotoh, K., & Xin, X. (2010). Optimality of a kip performance on the high bar: An example of skilled goal-directed whole-body movement. *Human Movement Science*, 29, 464-482.

Youdas, J. W., Amundson, C. L., Cicero, K. S., Hahn, J. J., Harezlak, D. T., & Hollman, J. H. (2010). Surface electromyographic activation patterns and elbow joint motion during a pull-up, chin-up, or perfect-pullup™ rotational exercise. *The Journal of Strength & Conditioning Research*, 24, 3404-3414.