

## ORIGINAL SCIENTIFIC PAPER

# Effect of Ballistic Warm-up on Isokinetic Strength, Balance, Agility, Flexibility and Speed in Elite Freestyle Wrestlers

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## Abstract

The aim of this study is effect of ballistic warm-up on isokinetic strength, balance and some parameters in male elite freestyle wrestlers. Thirteen elite freestyle wrestlers at the age of  $20.15 \pm 2.11$  yrs, with  $174.54 \pm 7.14$  cm height and  $81.67 \pm 15.36$  kg weight participated in the study. Measurements were performed two different warm-up protocols. Running protocol at submaximal level on the treadmill for 10 minutes was applied for every wrestler. Ballistic Warm-up protocol involved 13 different movements for multi-muscle groups lasting for 10 minutes. Flexibility, speed, agility, balance, hand grip and isokinetic leg strength parameters were measured. Wilcoxon Signed Rank test was performed to find the difference between the protocols. Consequently, differences were found in flexibility, right hand grip strength, right posteromedial and posterolateral balance, left posteromedial and posterolateral balance, left and right hamstring and quadriceps strength parameters. Ballistic warm-up protocol can be more effective in many parameters, especially strength compared to ordinary warm-up.

**Key words:** freestyle wrestling, ballistic warm-up, isokinetic strenght, balance, agility

## Introduction

In wrestling, strength, speed, technique, practical intelligence and flexibility are required skills to pull, push, throw and lift the opponent, stop their attacks or outmaneuver them (Halloran, 2008). It is believed that proper and sufficient warm-up exercise enhances performance while reducing the risk of injury and muscle pains. There are a couple of stretching techniques called as static, ballistic, dynamic and PNF stretching that are preferred by athletes during warm-up time for various reason (Bacurau et al., 2009). The first method is static stretching meaning that target muscles or muscle groups are slowly elongated to stretching point and that position is held for a certain time (Costa, dos Santos, Prestes, da Silva, & Knackfuss, 2009). Static stretching, among diverse methods used in wrestling and many other branches, is frequently performed before exercise and athletic performance. It is widely accepted that static stretching increases flexibility and performance while reducing the risk of injury (Evetovich, Nauman, Conley, & Todd,

2003). However, while different studies presumed that static stretching cause a decline in strength production in relevant muscle groups, other scientists have recently found a decline in sprint speed as well (Chaouachi et al., 2008). Another type of static stretching is PNF (proprioceptive neuromuscular facilitation). Although not a stretching type exactly, it is a technique combining passive and isometric stretching to achieve maximum static flexibility. PNF is a method that a muscle group is passively stretched, then, isometrically contracted against resistance in this stretched position and finally, passively stretched through the increased range of motion, and it describes stretching techniques allowing relaxation after any isometric contraction (Bradley, Olsen, & Portas, 2007). In their study (Bradley et al., 2007) found that PNF stretching produces greater decrease in motor neuron activity compared to static stretching. Dynamic stretching is performed when a muscle is stretched to the movement limit of joint in a stretched position, and contraction and relaxation occur with subsequent



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repetitions, and this type of stretching also defined as the resistance of joint movement (Yamaguchi & Ishii, 2005). Although many studies present the positive effects of dynamic stretching (Yamaguchi, Ishii, Yamanaka, & Yasuda, 2007), athletes are recommended to combine static and dynamic stretching for a better harmony. However, the results of some studies indicate that static stretching may cause a decrease in performance in some cases and thus, the effect of dynamic stretching may decline as well (Amiri-Khorasani, Calleja-Gonzalez, & Mogharabi-Manzari, 2016). Mostly used in branches like gymnastic and dance that flexibility is highly effective, ballistic stretching is a method involving rhythmic springing after a short stretching (M.T. Woolstenhulme, Griffiths, E.M. Woolstenhulme, & Parcell, 2006). It generally involves springing, swinging, bouncing-rebounding and a sequence of rhythmic movements, and the terms like dynamic, fast, isotonic or kinetic are widely used to describe ballistic stretching. In this type of stretching, movement is repeated without stopping at pain threshold (Guissard & Duchateau, 2006) report that ballistic stretching stimulates stretching reflex thanks to its stimulating effects on homonymous alpha motor neuron firing (big lower motor neurons in brainstem) of type I and type II receptors in muscle spindle. The activation of this stretching reflex causes contraction in the stretched muscle (Woolstenhulme et al., 2006) maintain that ballistic warm-up is highly effective on high jump in basketball

players and recommend ballistic stretching exercise in basketball competitions and training. In the same study, they also state that ballistic stretching is more effective in increasing flexibility compared to static stretching. Various stretching activities for improving flexibility during warm-up differ in every training or sports branches. Trainers and athletes wish to know which stretching protocols are most useful for athletic performance during warm-up time before training. While some researchers claim that stretching does not affect performance negatively, some others point out its negative effect. Although not as much as a gymnast, high flexibility is necessary for wrestlers as well. Therefore, this study aims at examining the effect of ballistic warm-up on isokinetic strength, balance, agility, flexibility and speed in elite freestyle wrestlers.

## Methods

Thirteen elite male freestyle wrestlers at the age of  $20.15 \pm 2.11$  yrs, with  $174.54 \pm 7.14$  cm height and  $81.67 \pm 15.36$  kg weight participated in the study,  $26.78 \pm 4.43$  kg/m<sup>2</sup> body mass index and  $13.02 \pm 6.01\%$  body fat percentage values were taken as descriptive statistics (Table 1). In addition, resting heart beat was determined as  $75.38 \pm 8.14$  beats/min since a submaximal warm-up protocol with 70% intensity according to the Karvenon method was to be applied after running Measurements.

**Table 1.** Descriptive statistics

Variable	Mean±SD
Age (year)	20.15±2.11
Height (cm)	174.54±7.14
Weight (kg)	81.67±15.36
Body mass index (kg/m <sup>2</sup> )	26.78±4.43
Body fat percent (%)	13.02±6.01
Resting heart beat (beats/min)	75.38±8.14

## Study design

The research assessed flexibility, speed, agility, grip strength, balance and isokinetic leg strength. The assessments lasted for 2 days with 1 day interval. The first day, Measurements after running, a warm-up protocol at submaximal level for 10 minutes on the treadmill (Hp Cosmos, Germany) was applied to every wrestler, followed by measurements. After Ballistic Warm-up protocol involving 13 different movements lasting for 10 minutes was applied to the wrestlers who had rested for 1 day and then, again the measurements followed. Participation was on a voluntary basis and the wrestlers signed a consent form. They were informed about the assessments in detail. It was considered that assessments were made while the wrestlers delivered their best performance. Before each measurement, the subjects were allowed to practise to understand the test and then, measurement was performed. It was repeated 5 times at the angular speed of 60 degree. Ballistic warm-up was performed with 13 different movements lasting for 10 minutes. Each wrestler performed warm-up exercise under the supervision of a trainer and with a video projected on wall through an overhead projector. There was no interval between the movements and utmost attention was given to perform the warm-up protocol as correctly as possible.

Ballistic warm-up movements are as follows: 1. Side leg swing on the bar; 2. Front leg swing on the bar; 3. While standing, passing to push-up position on hands. In facedown position with hands put on the ground, stretching by twisting the waist backward and standing up by walking on hands again; 4.

Stretching forward by raising arms straight and trying to touch the head to knees while legs are brought to a stretched position; 5. Right and left stretching in a persistent and rhythmic way; 6. Stretching forward in front bench position and throwing the head backward with back open; 7. Opening legs shoulder width apart and bouncing down to touch on right foot and opening up right arm. Then, touching on left foot and opening up left arm; 8. Passing through the anterior knee (frontal passe) standing on foot, taking a side passe position and lowering it. Side passe, taking frontal passe position and lowering it; 9. Walks with right and left legs; 10. Passing through the knee, stretching the knee with hand, rising on tiptoes and taking steps. Repeating the same exercise with the other leg; 11. Pulling right front knee and bounding. Then, pulling left front knee and bounding; 12. Wide-move walking with right and left leg; 13. Putting the heel a foot ahead, holding the foot, pulling the tiptoe toward yourself and reaching forward, and touching the head to the knee. Repeating the same exercise with the other leg.

## Testing Measurements

Tanita: Bioelectrical impedance from foot to foot was measured using the Tanita-305 body-fat analyser (Tanita Corp., Tokyo, Japan) which provides a print-out of measured impedance and calculated body fat.

Hand Grip Strength: Hand grip strength was measured using hand dynamometer.

Sit-and-reach flexibility: The sit-and-reach test was con-

ducted using the Flex-Tester apparatus (Novel Products Inc., USA).

20-m sprint run: The 20-m sprint test was performed on an indoor synthetic 60 m sprint track.

Y Balance: Balance was measured through Y balance test.

Agility: To assess agility, the Illinois agility test was performed.

Resting Heart Beat: Resting heart beat was recorded using telemetry (Polar Oy Finland). Your pulse at rest (the best time to get a true resting heart rate is first thing in the morning before you get out of bed).

Isokinetic Leg Strength: Biodex system was measured by 3 pro isokinetic force dynamometer.

#### Statistical Analysis

Analysis of the data was done in the SPSS 22.0 package program. Descriptive statistics were shown as mean  $\pm$  standard deviation for discontinuous and continuous numerical variables. On the data acquired from the research, the Friedman test was performed to compare the results obtained from two different warm-up procedures, and the Wilcoxon Signed Rank test was performed to find the difference between the groups.

#### Result

When the data obtained from the research was evaluated, statistically significant differences were found in flexibility, right hand grip strength, right posteromedial and anterior balance, left anterior, posteromedial and posterolateral balance, right and left hamstring, and right quadriceps strength parameters in ballistic warm-up protocol.

When the averages were examined, it was found that the wrestlers group had best result with (Table 2): Flexibility (cm) 5.29% increased; Speed (sec) 0.72% increased; Agility (sec) 1.62% increased; Right hand grip strength (kg) 5.52% increased; Left hand grip strength (kg) 5.61% increased; Right anterior balance (cm) 2.27% decreased; Right posteromedial balance (cm) 5.82% increased; Right posterolateral balance (cm) 5.16% increased; Left anterior balance (cm) 0.41% decreased; Left posteromedial balance (cm) 4.58% increased; Left posterolateral balance (cm) 5.99% increased; Right hamstring 60°s-1 (N.m-1) 9.54% increased, Right quadriceps 60°s-1 (N.m-1) 3.77% increased; Right ratio 3.05% decreased, Left hamstring 60°s-1 (N.m-1) 5.92% increased; Left quadriceps 60°s-1 (N.m-1) 2.80% increased, Left ratio 0.62% decreased.

**Table 2.** Measurements after running and after ballistic warm-up

Parameter	After running	After Ballistic Warm-up	Sig.
Flexibility (cm)	35.00 $\pm$ 6.64	36.85 $\pm$ 5.81	.002*
Speed (sec)	31.89 $\pm$ 1.73	31.66 $\pm$ 2.03	.727
Agility (sec)	17.86 $\pm$ 1.11	17.59 $\pm$ 1.21	.382
Right hand grip strength (kg)	51.58 $\pm$ 7.71	54.43 $\pm$ 7.72	.003*
Left hand grip strength (kg)	52.02 $\pm$ 7.63	54.94 $\pm$ 5.73	.071
Right anterior balance (cm)	77.92 $\pm$ 4.80	76.15 $\pm$ 6.37	.324
Right posteromedial balance (cm)	105.62 $\pm$ 9.58	111.77 $\pm$ 7.92	.004*
Right posterolateral balance (cm)	99.62 $\pm$ 9.26	104.77 $\pm$ 12.53	.003*
Left anterior balance (cm)	75.54 $\pm$ 6.22	75.23 $\pm$ 5.703	.697
Left posteromedial balance (cm)	105.62 $\pm$ 7.56	110.46 $\pm$ 5.95	.000*
Left posterolateral balance (cm)	101.38 $\pm$ 9.68	107.46 $\pm$ 7.68	.002*
Right hamstring 60°s-1 (N.m-1)	140.33 $\pm$ 24.73	153.73 $\pm$ 23.76	.004*
Right quadriceps 60°s-1 (N.m-1)	221.93 $\pm$ 35.13	252.49 $\pm$ 32.32	.003*
Right ratio	63.08 $\pm$ 6.44	61.15 $\pm$ 8.25	.400
Left hamstring 60°s-1 (N.m-1)	141.67 $\pm$ 23.22	150.062 $\pm$ 24.78	.002*
Left quadriceps 60°s-1 (N.m-1)	235.76 $\pm$ 51.10	242.37 $\pm$ 57.38	.152
Left ratio	61.23 $\pm$ 8.20	60.85 $\pm$ 10.08	.838

#### Discussion

The aim of this study is to analyse the effect of ballistic warm-up on isokinetic strength, balance, agility, flexibility and speed in elite freestyle wrestlers. When the data obtained from the research was evaluated, statistically significant differences were found in flexibility, right hand grip strength, right posteromedial and anterior balance, left anterior, posteromedial and posterolateral balance, right and left hamstring, and right quadriceps strength parameters in ballistic warm-up protocol. Wrestling is a sport with many performance dynamics. To apply these dynamics at maximum level is important to be successful in training and competitions. Flexibility is usually included in the program of many sports branches as an important part of warm-up procedure. However, it is not right to limit performance with flexibility only. At the same time, there are many studies as to whether or not flexibility enhances athletic performance. In his study on wrestlers (Çelebi, 2014)

found no significant impact on strength when he compared static stretching, dynamic stretching and control group, but participants displayed a relatively better performance compared to the control group after static stretching and achieved relatively lower scores after dynamic stretching. Manoel, Harris-Love, Danoff and Miller (2008), Moran (2012) and Demirci (2013) found similar results in their studies conducted in different branches. Static stretching gives rise to criticism and discussions in many studies due to its negative or ineffective outcomes in competing athletes' performance (Çelebi, 2014; Kistler, Walsh, Horn, & Cox, 2010). Kistler et al. (2010) state that it is disadvantageous to include static stretching exercises in warm-up program for short distance races up to 100 m. Other studies found that static stretching during warm-up time has negative impact on athletes' maximal strength as well (Costa et al., 2009). In endurance sports, elite athletes are recommended to exclude static stretching techniques before

moderate-intensity cycling training because it reduces acute cycling economy (Wolfe, Brown, Coburn, Kersey, & Bottaro, 2011). In running, it was found that static stretching damages neuromuscular function that causes slow start (Damasceno et al., 2014). As is seen, there are many studies claiming that static stretching is not recommended before athletic competitions or activities requiring high levels of strength (Bradley et al., 2007). On the other hand, some researchers point out the increasing effects of dynamic stretching on performance in contrast to static stretching, or present results indicating that it does not have any negative effects (Bacurau et al., 2009; Curry, Chengkalath, Crouch, Romance, & Manns, 2009; Vetter, 2007). Yamaguchi and Ishii (2005) indicate that dynamic stretching exercises during warm-up time enhance strength. In addition, similar studies were conducted by Amiri-Khorasani et al. (2016), Colak, (2012), Faigenbaum, Bellucci, Bernieri, Bakker and Hoorens (2005), Gourgoulis, Aggeloussis, Kasimatis, Mavromatis and Garas (2003), Yamaguchi and Ishii (2005). Famisis (2015) found that the two dynamic flexibility protocols significantly enhance sprint pace. In another study conducted (Amiri-Khorasani et al., 2016) that DS during a warm-up is more effective than SS as a preparation to the abrupt acceleration and speed required in soccer. According to the results of the study (Chatzopoulos, Galazoulas, Patikas, & Kotzamanidis, 2014) DS protocol is more appropriate than SS for activities that require balance, rapid change of running direction (agility) and movement time of the upper extremities. The participants were 31 high school students who were basketball, handball, volleyball player or athlete. The first protocol involved 3 min jogging followed by 7 min static stretching. Second protocol consisted of 3 min jogging followed by 7 min dynamic stretching, and third protocol consisted of 3 min jogging followed by 7 min rest. Compared to static protocol, dynamic protocol performed better in balance, agility and movement time. In some sports branches, the significance of and relationship between flexibility and strength are very notable. Particularly, in such branches as gymnastic and dance that high levels of flexibility, agility and strength are important, ballistic stretching is heavily preferred in warm-up routines (Woolstenhulme et al., 2006). There are also studies asserting that recently popular ballistic stretching is less likely to reduce maximal strength and its exercises can be preferred. In their strength assessments conducted with freestyle weights, (Barroso, Tricoli, Santos Gil, Ugrinowitsch, & Roschel, 2012) found that static, ballistic and PNF stretching decrease the number of repetitions and total volume. In the study, static stretching resulted in 20.8% decrease in total volume while ballistic stretching resulted in 17.8% decrease. In another study examining the effects of ballistic and static stretching on maximal strength and flexibility, (Bacurau et al., 2009) reveal that static stretching reduces maximal strength while ballistic stretching does not have any impact on maximal strength. Woolstenhulme et al. (2006) found an acute increase in vertical jump after 20 minutes in a basketball group that performed ballistic stretching in training, and recommended to trainers to consider using ballistic warm-up protocol in trainings. Similarly, in their study on the impact of ballistic training on volleyball players' preseason prep time (Newton, 1999) observed a significant improvement in vertical jump performance in elite athletes thanks to ballistic training. On the other hand, Unick, Kieffer, Cheesman and Feeney (2005) examined the effects of static and ballistic stretching on verti-

cal jump performance in trained women and found that the two stretching protocols do not cause a significant difference in vertical jump performance. Samuel, Holcomb, Guadagnoli, Rubley and Wallmann (2008) state that static stretching and ballistic stretching do not have any effect on vertical jump, quadriceps and hamstring strength. However, Kumar and Chakrabarty (2010) found that after 6 week ballistic and static stretching exercise, ballistic exercise significantly increased the flexibility of hamstring muscles in athletes compared to static exercise. Guissard and Duchateau (2006) maintain that ballistic stretching stimulates stretching reflex. According to literature studies, it is found that stretching protocols can affect athletes' performance in different ways. Different exercises athletes perform during warm-up time can cause small positive increases or differences in their performance and scores, and such differences can change the outcome in competitions. Hence, each stretching protocol in warm-up time should be in line with the requirements and needs of the sports in question. Literature review reveals that different protocols produce different effects. While the effects of ballistic stretching have been assessed in many sport branches, no study was found on wrestling. Thus, this study attempted to examine the responses of freestyle wrestlers to ballistic stretching exercise and found that positive effects observed in other branches are also observed wrestling. The study assessed the freestyle wrestlers.

We can say that ballistic warm-up protocol in freestyle wrestlers can be more effective on performance in strength, flexibility and balance in particular compared to ordinary warm-up, and thus, ballistic exercises can be used as part of warm-up protocols.

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#### Conflict of Interest

The authors declare that there are no conflicts of interest.

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#### References

- Amiri-Khorasani, M., Calleja-Gonzalez, J., & Mogharabi-Manzari, M. (2016). Acute Effect of Different Combined Stretching Methods on Acceleration and Speed in Soccer Players. *J Hum Kinet*, 50, 179-186.
- Bacurau, R.F., Monteiro, G.A., Ugrinowitsch, C., Tricoli, V., Cabral, L.F., & Aoki, M.S. (2009). Acute effect of a ballistic and a static stretching exercise bout on flexibility and maximal strength. *J Strength Cond Res*, 23(1), 304-308.
- Barroso, R., Tricoli, V., Santos Gil, S.D., Ugrinowitsch, C., & Roschel, H. (2012). Maximal strength, number of repetitions, and total volume are differently affected by static-, ballistic-, and proprioceptive neuromuscular facilitation stretching. *J Strength Cond Res*, 26(9), 2432-2437.
- Bradley, P.S., Olsen, P.D., & Portas, M.D. (2007). The effect of static, ballistic, and proprioceptive neuromuscular facilitation stretching on vertical jump performance. *J Strength Cond Res*, 21(1), 223-226. doi:10.1519/R-21046.1
- Chaouachi, A., Chamari, K., Wong, P., Castagna, C., Chaouachi, M., Moussa-Chamari, I., & Behm, D.G. (2008). Stretch and sprint training reduces stretch-induced sprint performance deficits in 13- to 15-year-old youth. *Eur J Appl Physiol*, 104(3), 515-522.
- Chatzopoulos, D., Galazoulas, C., Patikas, D., & Kotzamanidis, C. (2014). Acute effects of static and dynamic stretching on balance, agility, reaction time and movement time. *J Sports Sci Med*, 13(2), 403-409.
- Colak, S. (2012). Effects of dynamic stretches on isokinetic hamstring and quadriceps femoris muscle strength in elite female soccer players. *South African Journal for Research in Sport, Physical Education and Recreation*, 34(2), 15-25.
- Costa, E.C., dos Santos, C.M., Prestes, J., da Silva, J.B., & Knackfuss, M.I. (2009). Acute effect of static stretching on the strength performance of jiu-jitsu athletes in horizontal bench press. *Fitness & Performance Journal (Online Edition)*, 8(3), 212-217.

- Curry, B.S., Chengkalath, D., Crouch, G.J., Romance, M., & Manns, P.J. (2009). Acute effects of dynamic stretching, static stretching, and light aerobic activity on muscular performance in women. *J Strength Cond Res*, 23(6), 1811-1819. doi:10.1519/JSC.0b013e3181b73c2b
- Çelebi, M. (2014). *The Effects Of Dynamic And Static Stretching Protocols On Power Agility And Flexibility In Elite Wrestlers*. (Doctoral dissertation), The Graduate School Of Social Sciences, Middle East Technical Universty Ankara.
- Damasceno, M.V., Duarte, M., Pasqua, L.A., Lima-Silva, A.E., MacIntosh, B.R., & Bertuzzi, R. (2014). Static stretching alters neuromuscular function and pacing strategy, but not performance during a 3-km running time-trial. *PLoS One*, 9(6), e99238.
- Demirci, N. (2013). *Statik Germe ve Dinamik Ağırıklı Isınmanın Sıçrama Performansına Etkisi (The Effect of Static and Dynamic Weighted Heating on Jump Performance)*. Paper presented at the 5. Antrenman Bilim Kongresi (5th.Training Science Congress), Beytepe Ankara.
- Evetovich, T.K., Nauman, N.J., Conley, D.S., & Todd, J.B. (2003). Effect of static stretching of the biceps brachii on torque, electromyography, and mechanomyography during concentric isokinetic muscle actions. *J Strength Cond Res*, 17(3), 484-488.
- Faigenbaum, A.D., Bellucci, M., Bernieri, A., Bakker, B., & Hoorens, K. (2005). Acute effects of different warm-up protocols on fitness performance in children. *J Strength Cond Res*, 19(2), 376-381. doi:10.1519/R-15344.1
- Famisis, K. (2015). Acute effect of static and dynamic stretching exercise on sprint and flexibility of amateur soccer players. *Physical Training: Fitness for Combatives*.
- Gourgoulis, V., Aggeloussis, N., Kasimatis, P., Mavromatis, G., & Garas, A. (2003). Effect of a submaximal half-squats warm-up program on vertical jumping ability. *J Strength Cond Res*, 17(2), 342-344.
- Guisard, N. & Duchateau, J. (2006). Neural aspects of muscle stretching. *Exerc Sport Sci Rev*, 34(4), 154-158.
- Halloran, L. (2008). Wrestling injuries. *Orthop Nurs*, 27(3), 189-192; quiz 193-184.
- Kistler, B.M., Walsh, M.S., Horn, T.S., & Cox, R.H. (2010). The acute effects of static stretching on the sprint performance of collegiate men in the 60- and 100-m dash after a dynamic warm-up. *J Strength Cond Res*, 24(9), 2280-2284.
- Kumar, C.K. & Chakrabarty, S. (2010). A comparative study of static stretching versus ballistic stretching on the flexibility of the hamstring muscles of athletes. *British Journal of Sports Medicine*, 44(Suppl 1), i16-i16.
- Manoel, M.E., Harris-Love, M.O., Danoff, J.V., & Miller, T.A. (2008). Acute effects of static, dynamic, and proprioceptive neuromuscular facilitation stretching on muscle power in women. *J Strength Cond Res*, 22(5), 1528-1534.
- Moran, M.P. (2012). *The effects of static stretching warm-up versus dynamic warm-up on sprint swim performance*. The University of North Dakota.
- Newton, I. (1999). *The Principia: mathematical principles of natural philosophy*: Univ of California Press.
- Samuel, M.N., Holcomb, W.R., Guadagnoli, M.A., Rubley, M.D., & Wallmann, H. (2008). Acute effects of static and ballistic stretching on measures of strength and power. *J Strength Cond Res*, 22(5), 1422-1428.
- Unick, J., Kieffer, H.S., Cheesman, W., & Feeney, A. (2005). The acute effects of static and ballistic stretching on vertical jump performance in trained women. *J Strength Cond Res*, 19(1), 206-212.
- Vetter, R.E. (2007). Effects of six warm-up protocols on sprint and jump performance. *J Strength Cond Res*, 21(3), 819-823.
- Wolfe, A.E., Brown, L.E., Coburn, J.W., Kersey, R.D., & Bottaro, M. (2011). Time course of the effects of static stretching on cycling economy. *J Strength Cond Res*, 25(11), 2980-2984.
- Woolstenhulme, M.T., Griffiths, C.M., Woolstenhulme, E.M., & Parcell, A.C. (2006). Ballistic stretching increases flexibility and acute vertical jump height when combined with basketball activity. *J Strength Cond Res*, 20(4), 799-803.
- Yamaguchi, T. & Ishii, K. (2005). Effects of static stretching for 30 seconds and dynamic stretching on leg extension power. *J Strength Cond Res*, 19(3), 677-683.
- Yamaguchi, T., Ishii, K., Yamanaka, M., & Yasuda, K. (2007). Acute effects of dynamic stretching exercise on power output during concentric dynamic constant external resistance leg extension. *J Strength Cond Res*, 21(4), 1238-1244.