1-1-2012

Force Output Comparison between Six U.S. Collegiate Athletic Teams.

Caleb D. Bazyler
East Tennessee State University, bazyler@etsu.edu

George Beckham

Howard Gray

Guy Hornsby

Ashley A. Kavanaugh

See next page for additional authors

Force Output Comparison between Six U.S. Collegiate Athletic Teams.

Creator(s)
Caleb D. Bazyler, George Beckham, Howard Gray, Guy Hornsby, Ashley A. Kavanaugh, Christopher MacDonald, Satoshi Mizuguchi, Michael H. Stone, and Michael H. Stone

FORCE OUTPUT COMPARISON BETWEEN SIX U.S. COLLEGIATE ATHLETIC TEAMS

Kimitake Sato, Caleb Bazyler, George Beckham, Howard Gray, Guy Hornsby, Ashley Kavanaugh, Christopher MacDonald, Satoshi Mizuguchi, Meg Stone, and Mike Stone

East Tennessee State University, Johnson City, TN, USA

The aim of the study was to compare allometrically scaled peak force and the force at 250 ms between six U.S. collegiate sport teams using isometric mid-thigh pull. Ninety subjects performed maximum effort of isometric mid-thigh pull to measure force output. The data were averaged within the teams, and statistically compared between teams using one-way ANOVA (p=.01). Significant difference was found that men's soccer and baseball produced higher allometrically scaled peak force, and men's soccer, tennis, and baseball produced higher allometrically scaled force at 250 ms. The data indicates that not all sports possess similar strength characteristics because of the nature of the sports, and observed separation between gender. Teams such as volleyball and baseball showed higher coefficient of variation due to the various positions within their sports.

KEYWORDS: isometric mid-thigh pull, allometrically scaled force, physical characteristics.

INTRODUCTION: For coaches, having knowledge of a baseline of fitness and physical profiles of high level athletes are vital components of building athleticism and to succeed in sports. It is evident that starters and non-starters, pros and amateurs have significant differences in physical characteristics, especially for those sports that require a strength-power component (Barker, Wyatt, Johnson, Stone, O'Bryant, Poe, et al., 1993; Gall, Carling, Williams, & Reilly, 2010). As a number of previous studies investigated physical demands of various athletic populations, body composition, vertical jump height, sprint time, and VO_2 max are commonly used protocols (Gall et al., 2010; Ostojic, Mazic, & Dikic, 2006; Sporis, Jukic, Ostojic, & Milanovic, 2009). Previous studies also reported different characteristics in positions within team sports such as American football and soccer (Iguchi, Yamada, Ando, Fujisawa, Hojo, Nishimura et al., 2011; Robbins, 2011; Sporis et al., 2009). It is obvious that different positions have different playing roles to create successful teams, thus physical characteristics can be slightly different.

As mentioned above, vertical jump height is one of the typical testing protocols to measure lower extremity force/power output along with the actual jump height (Barker et al., 1993; Gall et al., 2010; Hoffman, Ratamess, Nesse, Ross, Kang, Magrelli et al., 2009; Iguchi et al., 2011; Ostojic et al., 2006; Robbins, 2011; Sporis et al., 2009). While countermovement jump or squat jump is a valid test, isometric mid-thigh pull also has been a well-established protocol for some years to measure force-power output to measure athletes' overall strength level (Haff, Stone, O'Bryant, Harman, Dinan, Johnson, et al., 1997; Stone, Sanborn, O'Bryant, Hartman, Stone, Proulx et al., 2003).

Although many studies investigated the physical characteristics of sport teams, none of the studies compared the difference or similarity in physical characteristics with multiple sports. Therefore, the purpose of the study was to determine the differences in allometrically scaled peak force and the allometrically scaled force at 250 ms between teams. Along with the peak force, the allometrically scaled force at 250 ms is also strongly related to jump height (Kraska, Ramsey, Haff, Fethke, Sands, & Stone, 2009), and the ability to produce large forces at 250 ms may be an important discrimination factor within and between sports. It was hypothesized that there would be higher scaled forces from baseball, as the sport is more strength-oriented than other teams. It was also hypothesized that there would be higher scaled forces from male teams than female teams.

METHODS: Ninety intercollegiate men (n=52) and women (n=38) participated in the study, which was part of an ongoing monitoring program (male: 179.8 ±7.2 cm, 82.6±8.5 kg; 14.2 ±5.5 body fat%; female: 167.3 ±7.9 cm, 67.5±7.6 kg; 22.46.3 ±4.1 body fat%). Subjects ranged age from 18 to 23, and in collegiate athletic experience at maximum of 5 years apart. Subjects signed consent forms in accordance with the university, athletic department, and sport science laboratory policies. The test was in accordance with the University Institutional Review Board.

Isometric mid-thigh pulls are a part of athlete monitoring tests to measure various kinetic variables. For the purpose of the current study, allometrically scaled peak forces were considered and measured the forces over a 91 cm x 91 cm force plate (Rice Lake, WI) sampling at 1,000 Hz in an immovable custom designed force rack (Figure 1). The apparatus and standard joint angles were established based on previous study (Haff et al. 1997). Immovable bar heights were set to the distances specific to each individual, with a knee angle of 125º ±5º and hip joint approximately at 175º ±5º. Performers' hands were attached to the bar using straps and athletic tape to ensure maximum efforts could be given for each pull without the limitation of hand grip (Haff, et al., 1997).

A warm up of 30 jump-jacks, a set of five repetitions of dynamic pulls from mid-thigh position with 20 kg, and two sets of five repetitions at 60 kg were performed for all subjects. Then two practice pulls of 50% and 75% effort were performed. Two maximal effort test trials (lasted ≈ 4 seconds) were completed with a rest of two minutes between trials. The two trials were averaged and calculated using an allometric scale to be comparable between athletes (Vanderburgh, 1999). The data was processed using LabView software (National Instruments Co., Austin, TX). The tests identify various forces at different time frames, and the two measurements (peak force & the force exerted at 250 ms) were selected based on the results of inter-correlated analysis. Since the number of subjects was different depending on the teams, Levene's test was conducted to identify the homogeneity of variances before the statistical analysis. One-way ANOVA was performed to identify the difference on scaled peak force and the force at 250 ms between the sport teams. *p* value was set at 0.01 for the significance.

Figure 1: The image of isometric mid-thigh pull.

RESULTS: The scaled peak force ($F(5,89)=17.931$, $p<0.0001$) and the scaled force at 250 ms ($F(5,89)=17.507$, $p<0.0001$) showed statistically significant differences. Descriptive data for each team are shown in Table 1. The follow-up post hoc tests were performed and identified that men's soccer and baseball were significantly different from other teams for the scaled peak force. Men's tennis, soccer, and baseball were significantly different from women's sport teams (tennis, soccer, & volleyball) for the force exerted at 250 ms. Further analysis was conducted by observing CV values from each team, and it is interpreted in discussion.

Table 1: Allometrically scaled forces on each sport teams (N / Kg$^{(2/3)}$)

Variables	M Tennis	W Tennis	M Soccer	W Soccer	W Volleyball	Baseball
*Peak force	202 ±32	171 ±20	259 ±28	187 ±22	190 ±45	241 ±39
*Force at 250 ms	141 ±27	105 ±28	172 ±30	117 ±15	129 ±32	174 ±30

*Significant difference, p <0.01.

DISCUSSION: The purpose of the study was to determine the difference of force outputs from isometric mid-thigh pull between D-1 U.S. collegiate sports teams. The study supported the hypothesis that there was a statistically significant difference in force output, showing the highest average was from men's soccer, followed by baseball and men's tennis for the scaled peak force. For the force at 250 ms, men's soccer and baseball were nearly identical, followed by men's tennis. All other teams (women's team) produced significantly lower forces than the men's teams, but displayed relatively similar data.

When considering the nature of the sports, soccer may be categorized as a physical and contact sport, and baseball may be categorized as strength-power oriented sport in which could be the reasons for higher average forces. When observing only women's teams, volleyball showed the highest average in both scales peak force and the force at 250 ms. This indicates that jump-oriented sports exerted higher forces than agility- and endurance-oriented sports (i.e., soccer & tennis).

For scaled peak force data, women's volleyball displayed the highest CV with 23.57%, followed by baseball with 16.22%, men's tennis with 15.86%. CV for women's soccer was 11.67%, women's tennis was 11.41%, and men's soccer was 10.81%. These are relatively small CV values indicating differences in strength level within teams are small. One possible reason for women's volleyball to have the highest CV may result from different physical characteristics for players in different positions. Physical characteristics such as height and mass are usually different between offensive players (taller & heavier) and defensive players (shorter & lighter).

Even though body composition was not a part of the current study interest, ranges of height, mass, and body fat percentage were close to the previously reported data in the relatively same age group (Gall et al. 2010; Hoffman et al., 2009; Sporis et al., 2009).

There are some limitations in this study. As a four-year university, there could be a higher force being produced by upper-class athletes (returners) as compared to in-coming athletes (new comers). Training volume in a collegiate setting is generally higher than high school level. Thus, it is possible that a ratio of upper-class and in-coming athletes influence the teams' data outcome. Additionally, the same idea could be applied to the analysis on positions within the sport teams. Previous studies supported that different positions have different physical profiles (Iguchi, et al., 2011; Robbins, 2011; Sporis et al., 2009), a ratio of offensive and defensive players with teams may also influence the data outcome, particularly on women's volleyball. As this testing protocol is on-going, this type of limitations could be solved in further study in future.

Having to know the difference in force output between the tested teams, it is important to discuss the strength demands in sports. It is obvious that strength-power is a necessary component of success in sports. There is no doubt that all tested teams in the present study require sport specific skills to be successful, but strength is also a vital component to improve their overall playing ability. This type of test should be utilized to monitor the progress over their collegiate career to be successful in their discipline.

CONCLUSION: Overall, the present study supported the concept that different scaled force outputs from different sport teams are present. Further assessment of the data need to be conducted and addressed in future study. As mentioned in the limitations, it is necessary to analyze the data depending on the years of exposure to the collegiate setting. It is also essential to know how much of difference among athletes within the sport teams is acceptable. In other words, if an individual performs poorly on the test as compared to his/her teammates, the athlete needs extra attention to improve overall strength level. A

baseline for all tested teams may be necessary to evaluate in-coming athletes. Periodically monitoring physical characteristics throughout athletes' collegiate career can result in an enhanced ability of sports scientists, sport coaches, and strength & conditioning coaches to create a protocol that optimally develops in-coming athletes throughout their collegiate career.

REFERENCES:

Barker, M., Wyatt, T.J., Johnson, R.L., Stone, M.H., O'Bryant, H.S., Poe, C., & Kent, M. (1993). Performance factors, psychological assessment, physical characteristics, and football playing ability. *Journal of Strength and Conditioning Research*, *7*(4)*,* 224-233.

Gall, F.L., Carling, C., Williams, M., & Reilly, T. (2010). Anthropometric and fitness characteristics of international, professional, and amateur male soccer players from elite youth academy. *Journal of Science and Medicine in Sport*, *13*, 90-95.

Haff, G.G., Stone, M.H., O'Bryant, H.S., Harman, E., Dinan, C.N., Johnson, R., & Han, K. (1997). Force-time dependent characteristics of dynamic and isometric muscle actions. *Journal of Strength and Conditioning Research*, *11*(4), 269-272.

Hoffman, J.R., Ratamess, N.A., Nesse, K.L., Ross, R.E., Kang, J., Magrelli, J.F., & Faigenbaum, A. D. (2009). Physical performance characteristics in national collegiate athletic association division III champion female lacrosse athletes. *Journal of Strength and Conditioning Research*, *23*(5)*,* 1524-1529.

Iguchi, J., Yamada, Y., Ando, S., Fujisawa, Y., Hojo, T., Nishimura, K., Kuzuhara, K., Yuasa, I., & Ichihashi, N. (2011). Physical and performance characteristics of Japanese division 1 football players. *Journal of Strength and Conditioning Research*, *25*(12)*,* 3368-3377.

Kraska, J.M., Ramsey, M.W., Haff, G.G., Fethke, N., Sands, W.A., Stone, M.E., & Stone, M. H. (2009). Relationship between strength characteristics and unweighted and weighted vertical jump height. *International Journal of Sports Physiology and Performance, 4*(4), 461-473.

Ostojic, S.M., Mazic, S., & Dikic, N. (2006). Profiling in basketball: physical and physiological characteristics of elite players. *Journal of Strength and Conditioning Research, 20*(4), 740-744.

Robbins, D.W. (2011). Positional physical characteristics of players drafted into the national football league. *Journal of Strength and Conditioning Research*, *25*(10)*,* 2661-2667.

Sporis, G., Jukic, I., Ostojic, S.M., & Milanovic, D. (2009). Fitness profiling in soccer: physical and physiological characteristics of elite players. *Journal of Strength and Conditioning Research*, *23*(7)*,* 1947-1953.

Stone, M.H., Sanborn, K., O'Bryant, H.S., Hartman, M., Stone, M.E., Proulz, C., Ward, B., & Hruby, J. (2003). Maximum Strength-power-relationship in collegiate throwers. *Journal of Strength and Conditioning Research*, *17*(4), 739-745.

Vanderburgh, P.V. (1999). A Simple index to adjust maximal strength measures by body mass. *Journal of Exercise Physiology Online,* 2(4), 7-12.

Acknowledgement: The authors would like to thank strength and conditioning coaches, sport coaches, and graduate assistants who are involved in data collection.