Original Article

Comparison of physical capacities strength and speed of different competition level football players

GISSIS IOANNIS

Sport Biomechanics Laboratory, Department of Physical Education and Sports Science Serres, Aristotle University of Thessaloniki, GREECE.

Published online: June 25, 2013

(Accepted for publication June 12, 2013)

DOI:10.7752/jpes.2013.02042;

Abstract

The aim of this study was to compare the physical capacities of strength and speed of soccer players of different competition level. Forty two (n=42) soccer players were divided into three groups according to competition level: football players of higher division (n=14), football players of middle division (n=14) and football players of lower division (n=14). All groups were evaluated for maximal isometric force, explosive force at 100 msec, peak force relative to body mass, rate of force development, squat and drop jump heights of 20 cm, drop jump heights of 30 cm, drop jump heights of 40 cm, pedaling rate and 10 m sprint time. Football players of higher division presented significantly ($p<0.05$) higher maximal isometric force, explosive force at 100 msec, vertical jump height, pedaling rate, and 10 m sprint time in comparison with the football players of middle division and football players of lower division. Also we observed statistically significant differences in selected variables between football players of middle division and football players of lower division.

Keywords: football players, maximal isometric force, explosive force at 100 msec, vertical jump performance, pedaling rate, sprint performance

Introduction

There are several studies in literature that report soccer is a dynamic, complex, and particularly demanding sport. Soccer, as a typical intermittent-type sport, incorporates various explosive motions such as sprinting, kicking, jumping, tackling, changes of direction, and turning (Reilly, Bangsbo, Franks, 2000; Reilly, Hoff, Helgerud, 2004; Wisloff, Castagna, Helgerud, Jones, Hoff, 2004; Mohr, Krustup, Bangsbo, 2005; Bangsbo, Mohr, Krustup, 2006; Spori, Jukic, Ostojic, Milanovic, 2009). Strength, power, and their derivatives, acceleration, all make important contributions to the performance potential of soccer players (Reilly, Bangsbo, Franks, 2000; Hoff & Helgerud, 2004). There are also reports in the literature concerning investigations which studied the strength of soccer players (Oberg, Moller, Gillquist, Ekstrand, 1986; Wisloff, Helgerud, Hoff, 1998; Cometti, Maffiuletti, Pousson, Chatard, Maffulli, 2001; McBride, Triplett-McBride, Davie, Newton, 2002; Newman, Tarpenning, Marino, 2004; Ronnestad, Kvamme, Sunde, Raastad, 2008; Tønnessen, Shalfawi, Hauge, Enoksen, 2011) and the speed of football players (McBride et al., 2002; Newman et al., 2004; Ronnestad et al., 2008; Tønnessen et al., 2011). In addition we can see significant differences between soccer players of different levels of competition, and soccer teams of different divisions in strength, vertical jump, and sprint performance (Oberg et al., 1986; Cometti et al., 2001; McBride et al., 2002; Newman et al., 2004; Ronnestad et al., 2008).

The evaluation of force–time curve characteristics, vertical jump ability, and speed has been used for strength and speed diagnosis and to monitor the effects of training in soccer players (Oberg et al., 1986; Cometti et al., 2001; McBride et al., 2002; Newman et al., 2004; Ronnestad et al., 2008; Gissis et al., 2006; Gissis, 2012). The purpose of this study was to assess the physical abilities of strength and speed of soccer players of different divisions, In order to draw conclusions which will be used in training plans.

Methods

Participants

Forty two (n=42) soccer players were divided into three groups according to competition level: elite class football players of higher division (n = 14), middle class football players of middle division (n = 14) and lower class football players of lower division (n = 14) (Table 1).

Table 1. Physical Characteristics of the Subjects (Means Values $\pm$ SD

	Age (years)	Height (cm)	Body mass (kg)
Elite class football players of higher division (n = 14)	23.5 $\pm$ 2.54	179.1 $\pm$ 3.5	76.19 $\pm$ 4.7
Middle class football players of middle division (n = 14)	22.9 $\pm$ 2.92	178.6 $\pm$ 4.1	77.24 $\pm$ 5.4
Lower class football players of lower division (n = 14)	23.2 $\pm$ 2.79	177.8 $\pm$ 4.5	78.32 $\pm$ 6.2

Measure

The measurements were conducted in the Sport Biomechanics Laboratory of the Department of Physical Education in Serres (Aristotle University of Thessaloniki).

Isometric Force

A specially designed leg-press apparatus was used for the measurement. Maximal isometric force of the bilateral leg extensor muscles was measured in a sitting position (knee and hip angle 90 degrees) (Gissis, I., Papadopoulos, C., Kalapotharakos, V.I., Sotiropoulos, A., Komsis, G., Manolopoulos, E., 2006; Papadopoulos, C., Kalapotharakos, V.I., Nousios, G., Meliggas, K. Gantiraga, E., 2006; Gissis, 2012). Three trials were completed by each participant, separated by 3 min. intervals, and the best performance was used for the subsequent statistical analysis. During maximum isometric effort a non movable-back chair was supporting the trunk, while the subjects had their hands on the dynamometer grips. Calibration of the measurement system was achieved by using weights (5, 10, and 20 kg weight discs) from 50 to 600 kg. Input (input = weight) and output values (output = electric signal) presented a distinct linearity. Reliability indexes ranged from .92 to .95 for the isometric strength.

Vertical Jump Ability

Vertical jump ability was evaluated using a one-dimensional dynamometer. Before the initiation of the measurements, a 10 min warming up was applied. All participants performed the following laboratory test items: a) squat jump from a static semi-squatting position with a knee angle 90° without using arms, b) drop jump from stands of 10 cm, c) drop jump from stands of 20 cm, d) drop jump from stands of 30 cm and e) drop jump from stands of 40 cm (Bobbert, Huijing, van Ingen Schenau 1987; Papadopoulos et al. 2006). Participants performed three trials for each test and the best trial was recorded. The dynamometer was connected to an A/D transformation card, a Pentium III computer with a math processor, and specially designed software for data reception and processing. Three trials were carried out for each type of jump, and the best result was used (test-retest reliability, $r = .90$).

Maximum Speed

A ergonomic bicycle was used for measurement of the highest speed on the ergometer, with no resistance. The speed was registered on a digital tachometer with measuring precision ± 0.01 Km/h. On the bicycle ergometer, the saddle height was individually adjusted for each person so that when the pedal was in the lowest position, the leg was straightened to 150 degrees. The subjects began slowly with an increasing pedaling rate, then accelerated fast and within a few seconds achieved their maximum speed, as the electronic speedometer indicated. If the subjects could not accelerate any further for 2 seconds, they had to break their attempt off, and their maximum achievement was recorded. Two trials were completed for each participant, separated by a 3 min rest interval, and the best performance was used for the subsequent statistical analysis (test-retest reliability, $r = .90$).

Sprint Performance

Ten meter sprint time was measured using an Autonics Beam Sensor, BL5M-MFR with a double laser beam and an automatic digital chronometer (Saint Wien Digital Timer Type H5K) having a resolution of 0.01 second and a measurement error of ± 0.01 sec. On command, subjects sprinted from a standing position. Three trials were completed for each participant, separated by a 3 min rest interval, and the best trial was used for the subsequent statistical analysis.

Assessed variables

Dependent variables in the present study were the maximum isometric force, the starting force achieved during the first 100 msec, the peak force relative to body mass, the rate of force development, vertical jump height, sprint time, and pedaling rate.

Statistical Analysis

The statistical package SPSS for Windows was used for all statistical analyses. Means + SD were calculated. One-way ANOVAs (with competition level as the independent factor) were applied to determine if there were differences among the three groups in all dependent variables. When F ratios were significant, post hoc comparisons of means were performed with Tukey's multiple comparison tests. Statistical significance was accepted at $p < .05$.

Results

One-way ANOVAs revealed significant effects of the group on maximal isometric force ($F_{(2,40)} = 37,230$, $p = 0,000$), peak force relative to body mass ($F_{(2,40)} = 59,426$, $p = 0,000$), explosiv force at 100 msec ($F_{(2,40)} = 38,860$, $p = 0,000$), rate of force development ($F_{(2,40)} = 85,399$, $p = 0,000$), squat jump height ($F_{(2,40)} = 6,362$, $p = 0,004$), drop jump height from 20 cm ($F_{(2,40)} = 12,980$, $p = 0,000$), drop jump height from 30 cm ($F_{(2,40)} = 3,250$, $p = 0,047$), drop jump height from 40 cm ($F_{(2,40)} = 25,442$, $p = 0,000$), pedalling rate ($F_{(2,40)} = 10,888$, $p = 0,000$) and 10 m sprint time ($F_{(2,40)} = 675,11$, $p = 0,000$).

Tukey's multiple comparison tests revealed that elite class football players showed significantly ($p < 0.05$) higher performance values in all dependent variables in comparison with the middle class football players and lower class football players (Table 2). We also observed significant differences in the above strength, vertical jump, and speed variables between middle class football players and lower class football players of lower division (Table 2).

Table 2. Strength and Speed Characteristics of Elite class football players of higher division, Middle class football players of middle division, and Lower class football players of lower division (Means Values SD)

	Elite class football players of higher division (n = 14)	Middle class football players of middle division (n = 14)	Lower class football players of lower division (n = 14)
Maximal isometric Strength (N)	2,092,943±119,078* [#]	1,944,509±69,343* ^o	1,824,484±76,062* ^o
Peak force relative to body mass	2,888±0.171* [#]	2,507±0.204* ^o	2,232±0.147* ^o
Explosive force at 100ms (N)	1,086,762±114,693* [#]	903,538±86,475* ^o	806,091±77,577* ^o
Rate of force development	60,450±7,482* [#]	57,852±8,829* ^o	55,664±9,735* ^o
SJ height (cm)	24,671±3.556* [#]	24,263±3.944* ^o	23,999±4.113* ^o
DJ20 height (cm)	25,345±3.803* [#]	24,770±3.982* ^o	24,384±4.255* ^o
DJ30 height (cm)	25,456±4.28* [#]	25,387±4.49* ^o	25,056±4.63* ^o
DJ40 height (cm)	26,490±4.458* [#]	26,019±4.686* ^o	25,247±4.860* ^o
Pedaling rate (Km/h)	81,090±3.132* [#]	80,035±3.295* ^o	79,289±4.246* ^o
10 m sprint time (sec)	1,9306±0.023* [#]	2,0047±0.033* ^o	2,035±0.051* ^o

SJ indicates squat jump; DJ20 indicates drop jump from 20 cm; DJ30 indicates drop jump from 30 cm; DJ40 indicates drop jump from 40 cm. *p < 0.05, significant differences between elite class football players (n = 14) and middle class football players (n = 14) #p < 0.05, significant differences between elite class football players (n = 14) and lower class football players (n = 14) ^op < 0.05, significant differences between middle class football players (n = 14) and lower class football players (n = 14)

Discussion

Apart from the maximum voluntary contraction (MVC), additional isometric force time characteristics, such as the starting force achieved during the first 100 msec (F100), and the time achieved to/for the MVC (TMVC) are important capacities of the neuromuscular system to develop maximal force rapidly, and are related to athletic performance (Hakkinen, Komi, Kauhanen, 1986; Papadopoulos, Salonikidis, Schmidtbleicher, 1997; Marcora, Miller, 2000; Kyrolainen, Avela, McBride, Koskinen, Andersen, Sipila, Takala, Komi, 2005; Gissis, et al., 2006; Gissis, 2012).

In present study elite class football presented significantly (p<0.05) higher maximal isometric force, reactive force index, in comparison with middle class football and lower class football players. We also observed significant differences between variables were chosen in middle class football players and lower class football players. For the footballer particular interest is the fact that the maximum power is an important factor in growth of strength and reaction force. Also the maximum force has a significant effect on power starting in explosive power. Players during the match is required to apply a set of movements like speeds both short and long, jumping, changing direction and tempo changes with maximum intensity (Stolen et al., 2005). From the existing forms of power, explosive or often called football strength is that where immediate and ideal level football and are therefore the player. In modern football but where longer apply new systems and regularly dominates the element of pressure in all areas needed a good power level footballers of all posts (Ramadan and Byrd, 1987; Rahkila & Luhtanen, 1991). The execution of a vertical jump is one of the key tests used to measure and evaluate the jumping ability of the athletes, the main goal is tested to produce the maximum power in a shorter time. The literature suggests a specific set of performance testers vertical jump, which is the indicator of the jumping ability of the test (Komi & Bosco, 1979; Bosco et al., 1982; Vobbert et al., 1996; Chou et al, 2001; Kubo et al., 2007; Liu et al., 2009; Pereira et al., 2009; Korff et al., 2009). A stretch-shortening cycle (SSC) can be defined as an active stretch (eccentric contraction) of a muscle followed by an immediate shortening (concentric contraction) of that same muscle (Komi & Bosco, 1979). Although explosive power has been extensively studied in lower body activities such as vertical jumping (Asmussen & Bonde-Petersen, 1974; Bosco & Komi, 1979; Bosco et al., 1982; Young & Bilby, 1993; Korff et al., 2009).

As regards the jumping ability, both horizontally and vertically jumps (tackles and ends) belong to the classic explosive actions in football. Jumps with one or both feet play a vital role in the possession or non-possession, to achieve or avoid goals. In present research, elite class football players presented significantly (p<0.05) higher vertical jump height, in comparison with the middle class football players and lower class young football players. We also observed significant differences between variables were chosen in middle class football players and lower class football players. These differences are probably caused because elite class football players of higher division might be due to their different muscle strength levels and coordination patterns.

A lot of previous studies has shown significant differences in vertical jump height among soccer players of different competition levels. On performance ability in the vertical leap of the players, has been found at relatively high levels in professional soccer players. Amateur players have significantly lower prices compared to professional footballers (Reilly & Thomas, 1979; Adhikari & Kumar, 1993; Wisloff et al., 1998).

In meaningful and effective actions in the game sprinting play a key role because it is a determining factor in the possession or non-possession, to achieve or avoid goals (Reilly, Bangsbo, Franks, 2000). In modern soccer requires highly developed ability acceleration. H acceleration ability of the player manifests in straight running speed (at distances of no more than 30m). In many situations the game with sprint distances traveled are single directions. Most of the time players have with the utmost speed to change direction. It was found that

players in a game make an average of 50 quick changes of direction (Wisloff et al., 2004). Regarding the ability to maintain the maximum speed has been reported to be reduced at the beginning of the second half compared with the first, leading to improvement programs deemed necessary resistance to sprint training in design at least twice a week (Mohr et al., 2003). In present study elite class football players run faster over 10 m, in comparison with the middle class football players and lower class football players. We also observed significant differences between variables were chosen in middle class football players and lower class football players.

The results agree with the results of studies where elite class football players were faster in 10m and 30m sprint compared middle class football players and lower class football players (Reilly et al., 2000; Ronnestad et al., 2008). In the comparison between professional and amateur players, there are no differences in maximum speed 30m, while professional football players showed significantly better performance in the retrospective distance of 10 meters (Cometti et al., 2001). This confirms the view that the ability to accelerate the player in a match is much more important than speed over long distances.

Conclusion

Summarizing, we can highlight the usefulness evaluating strength and speed of the players with the help of reliable test to base the results to design the most appropriate further coaching process.

References

- Adhikari, A., & Kumar, D. (1993). Physiological and physical evaluation of Indian national soccer squad. *Hungarian Review of Sports Medicine*, 34, 197-205.
- Asmussen, E., & Bonde-Peterson, F. (1974). Storage of elastic energy in skeletal muscle in man. *Acta Physiologica Scandinavica*, 91, 358-392.
- Bangsbo J. (1994). Energy demands in competitive soccer. *J. Sports Sci.*, 12:5-12.
- Bangsbo, J., Mohr, M., and Krstrup, P. (2006). Physical and metabolic demands of training and match-play in the elite soccer player. *J Sports Sci* 24: 665–674.
- Bosco, C. & Komi, P.V. (1980). Influence of aging on the mechanical behaviour of leg extensor muscles. *European Journal of Applied Physiology and Occupational Physiology*, 45, 209–219.
- Bosco, C., Viitasalo J.T., Komi, P.V., & Luthanen, P. (1982). Combine effect of elastic energy and myoelectrical potentiation during stretch-shortening cycle exercise. *Acta Physiologica Scandinavica*, 114, 557–565.
- Bobbert, I., Huijing, P., van Ingen Schenau, G. (1987). Drop Jumping II. The influence of dropping height on the biomechanics of drop jumping. *Medicine and Science in Sports and Exercise*, 19, 339–346.
- Cometti, G., Maffiuletti, N.A., Pousson, M., Chatard, J.C., Maffulli, N. (2001). Isokinetic strength and anaerobic power of elite, subelite and amateur French soccer players. *International Journal of Sports Medicine*, 22, 45–51.
- Cronin, J.B. & Hansen, K.T. (2005). Strength and power predictors of sports speed. *Journal of Strength and Conditioning Research*, 19, 349–357.
- Chou, P.H., Chou, Y.L., Lin, C.J., Su, F.C., Lou, S.Z., Lin, C.F., & Huang, G.F. (2001). Effect of elbow flexion on upper extremity impact forces during a fall. *Clinical Biomechanics*, 10, 888-94.
- Gissis, I., Papadopoulos, C., Kalapotharakos, V.I., Sotiropoulos, A., Komsis, G., Manolopoulos, E. (2006). Strength and speed characteristics of elite, subelite, and recreational young soccer players. *Research in Sport Medicine*, 14(3), 205-214.
- Gissis, I. (2012). Evaluation of physical capacities of strength and speed of different competition level young football players. *Journal of Physical Education and Sport*, 12 (4), 544-549.
- Hakkinen, K., Komi, P.V., Kauhanen, H. (1986). Electromyographic and force production characteristics of leg extensor muscles of elite weight lifters during isometric, concentric, and various stretch-shortening cycle exercises. *International Journal of Sports Medicine*, 7, 144–151.
- Hakkinen, K. (1993). Neuromuscular fatigue and recovery in male and female athletes during heavy resistance exercise. *International Journal of Sports Medicine*, 14, 53–59.
- Hoff, J. & Helgerud, J. (2004). Endurance and strength training for soccer players: Physiological considerations. *Sports Med.*, 34, 165–180.
- Komi, P.V., & Bosco, C. (1978). Utilization of stored elastic energy in leg extensor muscles by men and women. *Medicine and Science in Sports and Exercise*, 10, 262-265.
- Kubo, K., Morimoto, M., Komuro, T., Yata, H., Tsunoda, N., Kanehisa, H., & Fukunaga, T. (2007). Effects of plyometric and weight training on muscle-tendon complex and jump Performance. *Medicine & Science in Sports & Exercise* 39(10), 1801-10.
- Kyrolainen, H., Avela, J., McBride, J.M., Koskinen, S., Andersen, J.L., Sipila, S., Takala, T.E.S., Komi P.V. (2005). Effects of power training on muscle structure and neuromuscular performance. *Scand J Med Sci Sports*, 15, 58–64.
- Korff, T., Horne, S.L., Cullen, S.J., Blazeovich, A.J. (2009). Development of lower limb stiffness and its contribution to maximum vertical jumping power during adolescence. *Journal of Experimental Biology*, 212(22), 3737-42.
- Liu, Y., Shih, S.M., Tian, S.L., Zhong, Y.J., Li, L. (2009). Lower extremity joint torque predicted by using artificial neural network during vertical jump. *Journal of Biomechanics*, 42(7), 906-11.

-
- McBride, JM, Triplett-McBride, T, Davie, A, Newton, RU. (2002). The effect of heavy- vs. light-load jump squats on the development of strength, power, and speed. *J Strength Cond Res* 16: 75-82.
- Marcora, S. & Miller, M. (2000). The effect of knee angle on the external validity of isometric measures of lower body neuromuscular function, *J Sports Sci.*, 18, 313-319.
- Mohr, M., Krustup, P., & Bangsbo, J. (2003). Match performance of high-standard soccer players with special reference to development of fatigue. *Journal of Sports Science*, 21, 519-528.
- Mohr, M, Krustup, P, and Bangsbo, J. (2005). Fatigue in soccer: A brief review. *J Sports Sci* 23: 593-599.
- Newman, S.A., Jones, G., Newham D.J. (2003). Quadriceps voluntary activation at different joint angles measured by two stimulation techniques, *Eur J Appl Physiol.*, 89 496-499.
- Newman M.A., Tarpenning K.M., Marino F.E. (2004). Relationships between isokinetic knee strength, single-sprint performance, and repeated-sprint ability in football players. *J. Strength Cond. Res.*, 18:867-872.
- Oberg B., Moller M., Gillquist J., Ekstrand B. (1986). Isokinetic torque levels for knee extensors and knee flexors in soccer players. *Int. J. Sports Med.*, 7:50-53.
- Orchard, J., Marsden, J., Lord, S., Garlick, D. (1997). Preseason hamstring muscle weakness associated with hamstring muscle injury in Australian footballers. *American Journal of Sports Medicine*, 25, 81-85.
- Papadopoulos, C., Salonikidis K. (2000). Diagnose und Auswertung der motorischen Fähigkeiten Kraft und Schnelligkeit bei jungen Schwimmern. *Leistungssport*, 4, 14-18.
- Papadopoulos, C., Kalapotharakos, V.I., Gantiraga, E., Nousios, G., Gissis, I. (2006). Laboratory strength measures of talented and less talented Greek children ages 9 to 10 years. *Perceptual and Motor Skills*, 102, 239-246.
- Papadopoulos, C., Kalapotharakos, V.I., Nousios, G., Meliggas, K. Gantiraga, E. (2006). The effect of static stretching on maximal voluntary contraction and force-time curve characteristics. *J Sport Rehabil.*, 15, 185-194.
- Pereira, G., de Freitas P.B., Rodacki, A., Ugrinowitsch, C., Fowler, N., & Kokubun, E. (2009). Evaluation of an innovative critical power model in intermittent vertical jump. *International Journal of Sports Medicine*, 30 (11), 802-7.
- Reilly, T., & Thomas, V. (1979). Estimating daily energy expenditure of professional association footballs. *Ergonomics*, 22, 541-548.
- Reilly, T., Bangsbo, J., Franks A. (2000). Anthropometric and physiological predispositions for elite soccer. *Journal of Sports Science*, 18, 669-683.
- Requena, B., González-Badillo, J.J., de Villareal, E.S., Erelina, J., García I., Gapeyeva, H., Pääsuke, M. (2009). Functional performance, maximal strength, and power characteristics in isometric and dynamic actions of lower extremities in soccer players. *J Strength Cond Res.*, 23 (5), 1391-401.
- Rønnestad, B.R., Kvamme, N.H., Sundé, A., Raastad, T. (2008). Short-term effects of strength and plyometric training on sprint and jump performance in professional soccer players. *J Strength Cond Res.*, 22 (3), 773-80.
- Sale, D. (1991). Testing strength and power. In MacDougall, J., Wenger, H., Green, H.. *Physiological Testing of the High Performance Athlete*. Champaign: Human Kinetics, 21-106.
- Schmidbleicher, D. (1992). Training for power events. In: Komi, P.V. (ed.) *Strength and Power in Sport*. Boston, 381-405.
- Sporis, G., Jukic, I., Ostojic, S.M., Milanovic, D. (2009). Fitness profiling in soccer: physical and physiologic characteristics of elite players. *J Strength Cond Res.*, 23 (7), 1947-53.
- Stolen, T., Chamari, K., Castagna, C., & Winsloff, U. (2005). Physiology of Soccer (An update). *Sports Medicine*, 35, 501-536.
- Tønnessen, E., Shalfawi, S.A., Haugen, T., Enoksen, E. (2011). The effect of 40-m repeated sprint training on maximum sprinting speed, repeated sprint speed endurance, vertical jump, and aerobic capacity in young elite male soccer players. *J Strength Cond Res.*, 25 (9), 2364-70.
- Vitasalo, J.T. & Aura, O. (1984). Seasonal fluctuation of force production in high jumpers. *Canadian Journal of Applied Sports Science*, 9, 209-213.
- Wisloff, U., Helgerud, J., Hoff J. (1998). Strength and endurance of elite soccer players. *Medicine and Science in Sports and Exercise*, 30, 462-467.
- Wisloff, U., Castagna, C., Helgerud, J., Jones, R., Hoff, J. (2004). Strong correlation of maximal squat strength with sprint performance and vertical jump height in elite soccer players. *British Journal of Sports Medicine*, 38, 285-288.
- Wong, P. L., Chamari, K., Dellal, A., Wisløff, U. (2009). Relationship between anthropometric and physiological characteristics in youth soccer players. *J Strength Cond Res.*, 23 (4), 1204-10.
- Young, W.B., & Bilby, G.E. (1993). The effect of voluntary effort to influence speed of contraction on strength, muscular power and hypertrophy development. *Journal of Strength & Conditioning Research*, 7, 172-178.
- Zabik, R.M. & Dawson, M.L. (1996). Comparison of force and peak EMG during a maximal voluntary isometric contraction at selected angles in the range of motion for knee extension. *Perceptual Motor Skills*, 83, 976-978.