ISOKINETIC LEG STRENGTH CHANGES IN YOUNG FEMALE SOUTH AFRICAN RECRUITS FOLLOWING BASIC MILITARY TRAINING

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Isokinetic testing was used to assess upper and lower leg isokinetic strength changes in 83 female recruits (age 20.2 ± 1.8 years; body mass 60.2 ± 9.2kg; stature 158.0 ±16.8cm) pre and post 12-weeks of basic military training. The cohort completed 48 periods of physical training incorporating a 10% weekly progression and 'Pole PT' exercises introduced from the fifth week of basic military training. No statistically significant ($p<0.05$) change in knee extension (60°/sec) and ankle dorsiflexion (30°/sec) measures were noted whilst knee flexion and ankle plantar flexion measures increased significantly by 11.5 % (Right)/ 5.5 % (Left) and 19.4 % (Right)/ 12.8 % (Left) from Pre-test to Post-test, respectively. The importance of considering isolated muscular testing rather than general muscular testing when assessing the effects of a training programme is highlighted.

KEYWORDS: plantar flexion, dorsiflexion, knee extension, knee flexion, physical.

INTRODUCTION: Physical training (PT) forms an integral part of Basic Military Training (BMT) with an increase in leg muscle strength often being one of the desired outcomes in new young recruits. Many studies have documented the favourable physical changes that occur with BMT in both male and female recruits (Williams, 2005, Santtila et al., 2008, Mattila et al., 2009). However, few studies have used isokinetic dynamometry to measure muscular strength changes of military recruits, with even fewer utilising this method on female recruits (Mahieu et al., 2006, Simpson et al., 2006). Muscular strength evaluation of the lower extremities has been frequently performed using free weights (Wisloff et al., 1998), or isoinertial (Murphy & Wilson, 1996) or isokinetic dynamometry (Murphy & Wilson, 1996; Lehance et al., 2009). Militaries have often opted to omit the muscular strength testing of the lower limbs and general muscular strength is normally evaluated utilizing the 1-minute sit-up and push up tests (Williams, 2005, Santtila et al., 2008, Mattila et al., 2009). Cost and logistical limitations possibly have been the reason for this. Isokinetic testing is widely used in strength assessment; however some authors believe that isokinetic dynamometry does not reflect the functional aspects of limb movements. Despite this concern the usefulness of isokinetic dynamometry in assessing muscular strength imbalances and deficits is undisputed, especially as it may be assumed that muscle strength and balance play a key role in muscle injuries (Lehance et al., 2009). The current study therefore tested the hypothesis that 12-weeks of BMT would alter the isokinetic strength of the upper and lower leg in female recruits.

METHODS: Ethical approval was obtained from both the South African Defence Force Ethics Committee and Ethics Committee of the Medical Faculty of the University of Pretoria to conduct the study. The 83 female participants (age 20.2 ± 1.8 years; body mass 60.6 ± 9.2kg; height 158.0 ±16.8cm) were volunteers from the South African Defence Force who had passed a medical entry examination executed by a medical officer. A pre-test post-test one group self-controlled experimental study design was used. No control group could be used as all military recruits who wish to be retained in military service need to successfully complete BMT, including the PT component, in the allocated 12-week period. Failure to do so results in dismissal. Informed consent was given by all study participants after an informative session was held explaining the objective of the study.

Instrumentation: The Cybex 340 was used for all testing and calibrated prior to each test period according to the specifications provided by the manufacturer (Cybex, 1988). The same researcher read the participants a standardized set of instructions to maintain consistency throughout the protocol. No visual or oral feedback was given to the participants on their performance as these types of feedback have been shown to alter isokinetic performance (Kimura et al., 1997). The positioning, stabilisation and set-up procedure as outlined by the Cybex 340 (1988) for seated knee extension/flexion and prone plantar/dorsi flexion was used together with a 7 minute warm-up on a stationary bicycle prior to the start of testing, a warm-up on the isokinetic dynamometer (3 submaximal, 3 maximal repetitions) with a 30 seconds rest prior to the start of the maximal test of 5 repetitions at 60 º/s for the knee extension/ flexion test and 30 º/s for the ankle plantar/ dorsi flexion test.
Procedure: Isokinetic testing was done at the start and finish of the 12-week BMT course on all recruits (n=83). This testing formed part of a battery of other measurements which have been reported elsewhere (Wood et al., 2010). Absolute (Nm) and relative (Nm/kg) changes in both knee extension/flexion (60° /sec) and ankle plantar/dorsiflexion (30° /sec) strength were recorded over 5 repetitions. A speed of 60° /sec and 30º/sec for testing knee extension/flexion strength and ankle plantar/dorsiflexion respectively have proven to be the most accurate and reliable measurements of knee and ankle torque (Levene et al., 1991, Möller et al., 2005).
Physical training programme intervention: The BMT activities included drill, regimental aspects, compliments and saluting, general military aspects, musketry, shooting, signal training, mine awareness, map reading, buddy aid, field craft, water orientation, parade rehearsal and PT. A total of 48 periods (40 min each) of PT were completed in the 12-week period (Department of Defence 2000). More details on the PT programme followed can be found in the literature (Wood et al., 2010). The PT programme ensured a 10% weekly progression in frequency and intensity of the initial training events (Heyward, 2002, Armstrong et al., 2004); resistance training exercises done against own body weight and solid timber wooden poles (pole PT) whilst two isolated and varied resistance exercises for each body region were performed at every PT session aimed at increasing the muscle strength of the recruits (Heyward 2002, Armstrong et al., 2004).
Statistical analysis: Data was analysed by means of the Statistical Product and Service Solutions package (SPSS 11.5 for Windows, SPSS Inc., Chicago, IL, USA). Descriptive statistics were calculated for all measurements. The paired sample t-tests for dependent samples were used to determine differences between the pre- and post-test measurement (Howell, 1992). An α level of 0.05 was used for all statistics.

RESULTS AND DISCUSSION: Total body mass did not change significantly from pre-test (60.2 ± 9.0kg) to post-test (60.0 ± 7.5kg). Absolute (Nm) and relative (Nm/kg) strength in both knee extension/flexion (60° /sec) and ankle plantar/dorsiflexion (30° /sec) recorded at the start and end of the 12-week BMT period are presented in Table 1.
Initial absolute isokinetic quadriceps strength was in line with the 1.8Nm/kg reported by Holmes and Alderink, (1984) for high school adolescents but was 9.4% below that reported by Fillyaw *et al.* (1986) for female university soccer players. This cohorts absolute flexor strength was however greater than the Fillyaw *et al.* (1986) group. The knee flexor-extensor ratio showed significant increases of 12.1% and 10.8% in the left and right limb, respectively. The increase in flexor strength accompanied by no improvement in knee extensor strength resulted in the knee flexor-extensor ratio increasing from the desired 60% to almost 70%, possibly predisposing the cohort to thigh injuries (Perrin, 1993). This highlights the need to revise the PT Programme to insure a sufficient training stimulus for knee extensor strength development. This cohort's initial isokinetic dorsiflexion and plantarflexion strength was far less than that reported of female college basketball players at the start of their competitive season (Payne *et al.,* 1997) and at the end of BMT these values remained lower at than those reported for the dorsiflexion of field hockey players at the end of their season (32.7±4.7Nm) (Naicker et al., 2007) and less than the plantarflexion (79.3Nm) reported by Berg et al., (1985) for basketball players at the end of their season. This may be attributed to

the initial comparative poor lower leg strength or to a difference in training programme followed by the field hockey and basketball players versus the BMT programme.

Table 1
Mean (SD) differences between Pre-test and Post-test isokinetic strength measurements of participants during 12 weeks of BMT

Isokinetic movement	Pre-test *N*		Pre-test Mean (SD)	Post-test *N*		Post-test Mean (SD)	t-test (p-value)
Knee extension (Nm)	*83*	L	111.6 (22.7)	*83*	L	110.9 (26.7)	0.1
		R	106.2 (23.7)		R	108.0 (20.0)	0.5
Knee flexion (Nm)	*83*	L	67.4 (12.8)	*83*	L	71.1 (14.1)*	0.01
		R	66.2 (17.0)		R	73.8 (13.0)*	0.001
Knee extension (Nm/kg)	*83*	L	1.9 (0.4)	*83*	L	1.8 (0.4)	0.1
		R	1.8 (0.4)		R	1.8 (0.3)	0.6
Knee flexion (Nm/kg)	*83*	L	1.1 (0.2)	*83*	L	1.2 (0.2)*	0.03
		R	1.1 (0.3)		R	1.2 (0.2)*	0.001
Knee flexor/extensor ratio (%)	*83*	L	61.3 (10.6)	*83*	L	68.7 (14.6)*	0.001
		R	63.1 (11.8)		R	69.9 (14.8)*	0.001
Ankle plantarflexion (Nm)	*83*	L	47.5(12.9)	*83*	L	53.6 (12.1)*	0.07
		R	44.3 (11.3)		R	52.9 (12.9)*	0.001
Ankle dorsiflexion (Nm)	*83*	L	20.00 (4.2)	*83*	L	19.7 (5.4)	0.6
		R	19.1 (3.7)		R	19.2 (5.3)	0.6
Ankle plantarflexion (Nm/kg)	*83*	L	0.8 (0.2)	*83*	L	0.9 (0.2)*	0.001
		R	0.8 (0.2)		R	0.9 (0.2)*	0.001
Ankle dorsiflexion (Nm/kg)	*83*	L	0.3 (0.1)	*83*	L	0.3 (0.1)	0.5
		R	0.3 (0.1)		R	0.3 (0.1)	0.5

*Significant change from the Pre-test to the Post-test at the end of 12 weeks of BMT. $p \leq 0.05$.

Although lower leg muscle endurance exercises specifically involving the quadriceps and calf muscles where completed by the recruits no statistically significant change in knee extension and ankle dorsiflexion values were measured after BMT, whilst knee flexion and ankle plantar flexion measures increased significantly by 11.5 % (R)/ 5.5 % (L) and 19.4 % (R)/ 12.8 % (L) from Pre-test to Post-test, respectively. The exercises and the progressive nature in which they were implemented during the BMT may have accounted for these changes, however the possibility exist that other activities which form part of the BMT, such as drilling may have counteracted the PT. Muscular strength overload was ensured by including exercises using wooden poles (5th week). Limited strength training facilities and large number of training recruits often renders strength training difficult to execute (Knapik et al., 2005). The “Pole PT” provided a cost-effective method of strength training based on the free-weight principle and may have contributed to the increase in strength observed (Heyward, 2002). This method of training may prove to be beneficial when coaches have large groups and financial constraints. This study highlights the benefit of measuring the strength of isolated muscle groups rather than general muscular testing when assessing training programme effectiveness as although lower limb muscle endurance exercises were completed it only rendered improvements in specific muscles in the legs and not all the muscles. The latter may provide false positive results whilst isolated muscle testing could focus on the risk of imbalance and implement antagonist strengthening aimed at injury prevention.

CONCLUSION: BMT altered the isokinetic strength of the upper leg flexor muscles and lower leg plantar flexor muscles in female recruits. The insignificant changes observed in the upper leg extensor and dorsiflexor muscle group and the increase in the knee flexor-extensor ratio going from the desired 60% to almost 70%, possibly predisposing the cohort to thigh injuries, highlights the need to revisit the PT programme used in this BMT as well as the importance of isolated muscle group testing when assessing the effects of a training programme.

REFERENCES:

Armstrong, D.W., Rue, J.P.H., Wilckens, J.H. & Frassica, F.J. (2004). Stress fracture injury in young military men and women. *Bone,* 35 (3): 806-816.

Berg, K., Blanke, D & Miller, M. (1985). Muscular fitness profile of female college basketball players. *Journal of Orthopeadic and Sports Physical Therapy, 7* (2): 59-64.

CYBEX 340. (1988). *Extremity Testing and Rehabilitation System User's Manual.* Ronkonkoma, New York: Cybex, Division of Lumex, Inc.

Department of Defence on physical training, *Department of Defence Instruction*: SG no 00006/2000.

Fillyaw, M., Bevins, T. & Fernandez, L. (1986). Importance of correcting isokinetic peak torque for the effect of gravity when calculating knee flexor to extensor muscle ratios.*Physical Therapy,* 66 (1):23-31.

Heyward, V. (2002). *Advanced Fitness Assessment and Exercise Prescription (4th ed.).* Champaign, Illinois: Human Kinetics.

Holmes, J.R. & Alderink,G.J. (1984). Isokinetic strength characteristics of the quadriceps femoris and hamstring muscles in high school students. *Physical Therapy,* 64 (6), 914–918.

Howell, D.C. (1992). *Statistical Methods for Psychology (3rd ed.).* Belmont: Duxbury Press.

Kimura, I.F., Gulick, D.T.& Gasiewski,E. (1997). Effect of visual feedback on concentric peak torque production during knee extension and flexion exercise in males and females. *Isokinetics and Exercise Science*, 6 (4), 209-214.

Knapik, J.J., Darakjy, S., Scott, S.J., Hauret, K.G., Canada, S., Marin, R., Rieger, W. & Jones, B.H. (2005). Evaluation of a standardized physical training program for Basic Combat Training. *Journal of Strength and Conditioning Research,* 19 (2): 246-253.

Lehance, C., Binet, J., Bury, S.T. & Croisier, J.L. (2009). Muscular strength, functional performances and injury risk in professional and junior elite soccer players, *Scandanavian Journal of medicine and Science in Sports,* 19(2):p243-251.

Levene, J.A., Hart, B.A., Seeds, R.H. & Fuhrman, G.R. (1991). Reliability of reciprocal isokinetic testing of the knee extensors and flexors. *Journal of Orthop. & Sports Physical Ther,* 14 (3), 121-126.

Mahieu, N.N., Witvrouw, E., Stevens, V., Van Tiggelen, D. & Roget, P. (2006). Intrinsic risk factors for the development of achilles tendon overuse injury: A prospective study. *The American Journal of Sports Medicine,* 34 (2): 226-235.

Mattila, V.M., Tallroth, K., Marttinen, M. & Pihlajamaki, H. (2007). Physical fitness and performance. Body composition by DEXA and its association with physical fitness in 140 conscripts. *Medicine and Science in Sports and Exercise,* 39 (12): 2242-2247.

Möller, M., Lind, K., Styf, J. & Karlsson, J. (2005). The reliability of isokinetic testing of the ankle joint and a heel-raise test for endurance. *Knee surgery, Sports Traumatology, Arthroscopy*, 13(1), 60-71.

Murphy, A.J. & Wilson, G.J. (1996). The assessment of human dynamic muscular function: a comparison of isoinertial and isokinetic tests. *Journal of Sports Med. & Phys. Fitness*, 36 (3), 169–177.

Naicker, M., McLean, M. Esterhuizen, T. & Peters-Futre, E. (2007). Poor peak dorsiflexor torque associated with incidence of ankle injury in elite field female hockey players. *Journal of Science & Medicine in Sport*, 10(6), 363-9.

Perrin, D.H. (1993). *Isokinetic exercise and assessment***.** Champaign, Illinois: Human Kinetics.

Payne, K.A., Berg, K. & Latin, R.W. (1997). Ankle injuries and ankle strength, flexibility, and proprioception in college basketball players. *Journal of Athletic Training,* 32 (3): 221-225.

Rochcongar, P. (2004). Isokinetic thigh muscle strength in sports: a review. *Annales de Réadaptation et de Médecine Physique*, 47(6), 274-281.

Santtila, M.; Häkkinen, K.; Laura, K.; Heikki, K.(2008). Changes in cardiovascular performance during a 8-week military Basic Training period combined with added endurance or strength training. *Military Medicine*, 173 (12): 1173-1179.

Simpson, J. Gray,C. & Florida-James, D. (2006). Physiological variables and performance markers of serving soldiers from two "elite" units of the British Army. *Journal of Sports Sciences,* 24 (6): 597-604.

Williams, A.G. (2005). Effects of Basic Training in the British Army on regular and reserve army personnel. *Journal of Strength and Conditioning Research,* 19 (2): 254-259.

Wisloff, U., Helgerud, J. & Hoff, J. (1998). Strength and endurance of elite soccer players. *Medicine and Science in Sports and Exercise*, 30(3), 462–467.

Wood, S., Krüger, E. & Grant, C. (2010). DEXA-assessed regional body composition changes in young female military soldiers following 12-weeks of periodised training. *Ergonomics*, 53, (4),537–547.