COLLEGIATE CROSS-COUNTRY AND TRIATHLON ATHLETES: A PHYSIOLOGICAL AND BIOMECHANICAL PROFILE

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INTRODUCTION: Highly trained endurance athletes typically possess low body mass and fat content, high aerobic power, high lactate thresholds and good sport specific efficiency. Given the specific endurance sport, athletes must also produce a wide range of movement velocities during a race or training event. For example, distance runners must maintain relatively average velocities yet be able to sprint when necessary (Furlong & Egginton, 2018). Furthermore, there may be differences in physical, physiological and biomechanical variables between men and women such as height, weight, vertical jump, and muscular strength (Fuster, Jerez, & Ortega, 1998). While studies show that biomechanical and physiological parameters are individually important for performance and training, rarely are they studied together. An integrated approach would provide athletes and coaches with a holistic profile that may better inform performance and training. The goal of this study was to characterize the biomechanical and physiological characteristics of cross country and triathlon athletes using a modified Bruce Protocol during a bout of running.

METHODS: Twelve collegiate cross-country and triathletes at the Division I and Division II level participated in the study. Exercise consisted of jump and aerobic power measures. Physiological variables included glucose and lactate measures. Testing day consisted of the following in sequential order: height and weight → Unweighted countermovement jumps (CMJ) → $\dot{V}O_{2max}$. After a standard warm-up, 3 CMJs were performed using dual Pasco force plates (Roseville, CA, USA). Jump mechanical characteristics were analyzed using ForceDecks software (VALD Performance,

London, UK); jump vertical ground reaction force (vGRF) were used as a comparison with running vGRF (RvGRF). Aerobic power was measured using a modified Bruce Protocol test, Tuff Tread treadmill (Conroe, TX, USA) and a ParvoMedics TrueOne 2400 metabolic cart (Sandy, UT, USA) was used for analyzing gas exchange. The treadmill was instrumented with a force plate (Rice Lakes, WI, USA); vGRFs for the right and left legs sampling at 1000 Hz. The variables were monitored continuously throughout the treadmill test and analyzed using LabVIEW (National Instruments, TX, USA). Variables measured included bilateral vGRF, blood glucose, blood lactate and maximum aerobic power ($\dot{V}O_{2max}$). Aerobic power: baseline measures were collected after the subject was seated for 3 minutes, exercise began at 10.1 kilometers per hour (km/h), speed increased every 2 minutes by 1.2 km/h until an RER of 1.0 was reached, speed then increased by 1.2 km/h each minute until volitional fatigue, treadmill inclination was 0° throughout. RPE, blood glucose (Accu-check Aviva Plus, Roche, Indianapolis, IN, USA), and blood lactate (Nova Medical Lactate Plus, Waltham, MA, USA) were measured at rest and at the end of each stage of aerobic power testing via a finger prick.

Statistical Analysis: Results from males and females were compared using an unequal variance, independent samples t-test (alpha was $p \leq 0.05$). A correlation between running asymmetry and jumping asymmetries was conducted. Data are presented as mean and standard deviation between males and females.

RESULTS: Test reliabilities for vGRF per running speed with a 95% confidence interval ranged from 0.97 to 1.00 throughout all speeds. Twelve athletes completed the study, 8 females (19.9±1.6 yrs, 166.1 ± 4.6 cm, 62.6 ± 7.1 kg) and 4 males (19.4 ± 1.5 yrs, 169.6 ± 10.1 cm, 70.0 ± 12.3kg). Even when scaled for individual body mass, males had statistically higher average vGRF values throughout the running test and jump asymmetry was noted for both males and females, however, no statistical significance was found with the small correlations between running and jumping asymmetries were found (*r*=0.37, *p*=0.236;*r*=-0.21, *p*=0.512) (Table 1).

TABLE 1. Average biomechanical characteristics throughout $\dot{V}O_{2max}$ test.

Variable	All Athletes (n=12)	Females (n=8)	Males (n=4)
RPvGRF (N/BM)	2.69 ± 0.19	2.50 ± 0.14	2.82 ± 0.22*
RvGRF Asymmetry	1.38 ± 0.68	1.33 ± 0.03	1.43 ± 0.04*
RLR	0.030 ± 0.007	0.024 ± 0.003	0.032 ± 0.006
RCT	202.96 ± 28.73	217.36 ± 24.59	201.14 ± 27.69
JPLFA	1.38 ± 15.69 (Right)	3.05 ± 14.97 (Right)	1.98 ± 20.96 (Left)*
JTPFA	2.34 ± 11.34 (Left)	1.33 ± 7.82 (Right)	9.68 ± 16.51 (Left)*

Notes: Test of all athletes are separated by gender. *denotes significant difference between males and females = $p \leq 0.05$. RPvGRF=Running Peak Ground Reaction Force; RvGRF=Running Ground Reaction Force; RLR=Running Loading Rate; RCT=Running Contact Time; JPLFA=Jumping Peak Landing Force Asymmetry; JTPFA=Jumping Takeoff Peak Force Asymmetry.

TABLE 2. Average physiological characteristics throughout $\dot{V}O_{2max}$ test.

Variable	All Athletes (n=12)	Females (n=8)	Males (n=4)
$\dot{V}O_{2max}$ (mL/kg/min)	53.37 ± 7.70	50.71 ± 5.51	61.23 ± 7.19*
MBG	121.00 ± 12.72	119.78 ± 14.57	128.50 ± 8.27*
MBL	13.48 ± 3.51	12.72 ± 3.78	15.93 ± 0.50*
MVe	117.25 ± 33.47	96.29 ± 15.27	159.15 ± 7.13*
MHR	193.08 ± 6.84	192.67 ± 7.55	193.25 ± 4.72
MRER	1.08 ± 0.10	1.05 ± 0.09	1.13 ± 0.11
MRPE	16.50 ± 2.61	16.00 ± 2.55	17.25 ± 2.63

Notes: Test of all athletes and separated by gender. *Significant difference between males and females = $p \leq 0.05$. MBG=Max Blood Glucose; MBL=Max Blood Lactate; MVe=Max Ve; MHR=Max Hear Rate; MRER=Max Respiratory Exchange Ratio; MRPE=Max Ratings of Perceived Exertion.

DISCUSSION: While comparison to previous research is difficult due to methodological differences, there are meaningful findings. First males and females showed quite different physiological as well as biomechanical characteristics which agrees (to an extent) with previous findings (Hutchinson, Cureton, Outz, & Wilson, 1991). Consistent with this study, Pappas and Carpes (2012), found females had a greater asymmetry than males during jump landings. JPLFA has been suggested to result in a higher injury potential (Bailey, Sato, Burnett, Stone, & performance, 2015). During the aerobic test, interestingly the males showed statistically greater peak and average force but not contact times. Thus, it appears that males produced greater average vertical forces resulting in reduced average contact times; suggesting greater stride length consistent with previous observations (Barnes, McGuigan, & Kilding, 2014); it is possible this would indicate that the males had greater efficacy at a given treadmill speed (Pavolainen, Hakkinen, Hamalainen, Nummela, & Rusko, 1999). Greater efforts, as a result of greater intensity would likely result in higher catecholamine response augmenting short-term exercise increases in blood glucose and lactate

(Brooks, Fahey, & Baldwin, 2005). Although not statistically different, males generally produced higher RERs (g=0.84) and RPEs (g=0.83); this is consistent with higher peak values for glucose and lactate suggesting that males may have made a greater effort.

CONCLUSION AND PRACTICAL APPLICATIONS: Expected differences between males and females were apparent. During treadmill running, evidence suggests that production of greater vGRF produces greater stride lengths and possibly mechanical efficiency advantages. Physiologically, the athletes had $\dot{V}O_{2max}$ values placing them in the 95th percentile or higher. Increasing the force producing capabilities of an athlete may enhance running performance, indicating that a sound strength training program may enhance these characteristics.

REFERENCES

Bailey, C. A., Sato, K., Burnett, A., Stone, M. H. (2015). Force-production asymmetry in male and female athletes of differing strength levels. *International Journal of Sports Physiology & Performance*, *10*(4), 504-508.

Barnes, K.R., McGuigan, M.R., & Kilding, A.E. (2014). Lower-body determinants of running economy in male and female distance runnings. *Journal of Strength & Conditioning Research, 28*(5), 1289-1297.

Brooks, G., Fahey, T., & Baldwin, K. (2005). *Exercise physiology: Human bioenergetics and its applications.* (4th ed.). Boston: McGraw-Hill.

Furlong, L., & Egginton, N. L. (2018). Kinetic Asymmetry during Running at Preferred and Nonpreferred Speeds. *Medicine and Science in Sports and Exercise, 50*(6), 1241-1248.

Fuster, V., Jerez, A., & Ortega, A. (1998). Anthropometry and strength relationship: male-female differences. *Anthropologischer Anzeiger*, 49-56.

Hutchinson, P., Cureton, K., Outz, H., & Wilson, G. (1991). Relationship of cardiac size to maximal oxygen uptake and body size in men and women. *International Journal of Sports Medicine, 12*(04), 369-373.

Pappas, E., & Carpes, F. P. (2012). Lower extremity kinematic asymmetry in male and female athletes performing jump-landing tasks. *Journal of Science and Medicine in Sport, 15*(1), 87-92.

Pavolainen, L., Hakkinen, K., Hamalainen, I., Nummela, A., & Rusko, H. (1999). Explosive-strength training improves 5-km running time by improving running economy and muscle power. *Journal of Applied Physiology, 86*(5), 1527-1533.