INFLUENCE OF BODY MASS INDEX ON ROWING KINEMATICS

Chris Richter, Stephanie Hamilton, Karen Roemer

Exercise Science, Health and Physical Education, Michigan Technological University, Houghton, Michigan, USA

Rowing meets the criteria for weight loss as defined by the American College of Sport Medicine. Little research exists on the influence of body shape on movement kinematics. Even if rowing is a non weight bearing exercise, the body shape may have an influence on rowing motion and joint reactions. This study investigated rowing movement kinematics between normal weight and overweight subjects. Differences were found for hip abduction and adduction angles. This knowledge can help to understand the influence of body weight and body shape on movement kinematics and can help to avoid overloading the joints.

KEYWORDS: Rowing, motion analysis, body shape

INTRODUCTION: Rowing combines endurance exercise as well as resistance training and has a favorable influence on health and the prevention of diseases. Studies have shown that rowing reduces the risks of falls, limb disability and coronary artery diseases (Yoshiga & Higuchi, 2002). Rowing also has a positive influence on the risk of developing type 2 diabetes, blood pressure, the ability to oxidize long chain fatty acids, the metabolic rate, glycogenic control, lipoprotein profile, hypertension and increases the fat-free mass (Sanada et al., 2009). In order to lose weight rowing can be a beneficial sport for all individuals because it is non-weight bearing and may not produce excess joint forces. Rowing meets all criteria for weight loss as defined by the American College of Sport Medicine (Sanada et al., 2009). However, the body shape may have an influence on rowing motion. Current studies show that body shape influences human gait. Changes in movement angles and increased joint forces in walking are well documented (cf. Browning et al., 2007; Lai et al., 2008). The aim of this study was to compare and analyze the rowing motion of over and normal weight individuals. Assessing kinematics during rowing in over and normal weight individuals may lead to manipulation in ergometer design to decrease the risk of injury.

METHODS: The World Health Organization (WHO) recommended classification of body shapes with the help of the Body Mass Index (BMI). The classifications in Table 1 were adopted in this study.
Ten overweight (five men, five women) and ten normal weight volunteers (five men, five women) with no or little previous rowing experience were recruited. Table 2 shows the characteristic data of the subjects. Exclusion criteria for participants included any past or current neurological or cardiovascular illness and any pain, which might affect their rowing motion. Prior to the investigation, all subjects gave informed consent according to the human subject ethics approval of the Institutional Review Board.

Table 1. Classification for body shapes

Class	BMI (kg/m^2)
Normal weight	18.5-24.9
Over weight	25-29.9
Obese	≥ 30

WHO (2004)

Table 2. Means and standard deviations of age, height, weight and BMI of overweight and normal weight subjects

	Normal weight	Over weight
Sample	10 (5 F & 5 M)	10 (5 F & 5 M)
Age (years)	27.4 ± 7.2	24.1 ± 5.9
Height (meter)	1.74 ± 0.08	1.71 ± 0.09
Weight (kg)	66.5 ± 9.2	78.1 ± 9.3
BMI (kg/m²)	21.8 ± 0.5	26.7 ± 0.4

A motion analysis system (Vicon, MX+, Oxford, United Kingdom) was used to collect kinematic data. Body mass, height, and body composition were measured of all subjects by a segmental body composition analyzer (Tanita, BC-418 Pro, Arlington Heights, USA), as well as segmental measurements of the whole body. The subjects were asked to wear tight fitting non-reflective clothes. Reflectors on shoes or clothes were covered by tape. 34 reflective markers where attached to the subject with double-faced adhesive tape (see Figure 1). Also, the rowing ergometer (Concept2, Model E, Morrisville, USA) was equipped with 13 markers (front and back of the ergometer, left and right handle, seat, upper footrest, lower footrest, footrest heel and middle seat). After an introduction on the rowing technique, the subjects performed a short warm-up to practice the rowing technique at a desired stroke rate (23-25 strokes per minute). Each subject rowed at three different resistance levels (3, 5 and 7) for two minutes each and had a break of two minutes between the trials. The second minute of the rowing interval was captured with a frequency of 200Hz. The Man-Model Dynamicus program (Alaska 6.01, Institute of Mechatronics, Chemnitz, Germany) was used to reconstruct the motion and calculate velocities and joint angles.

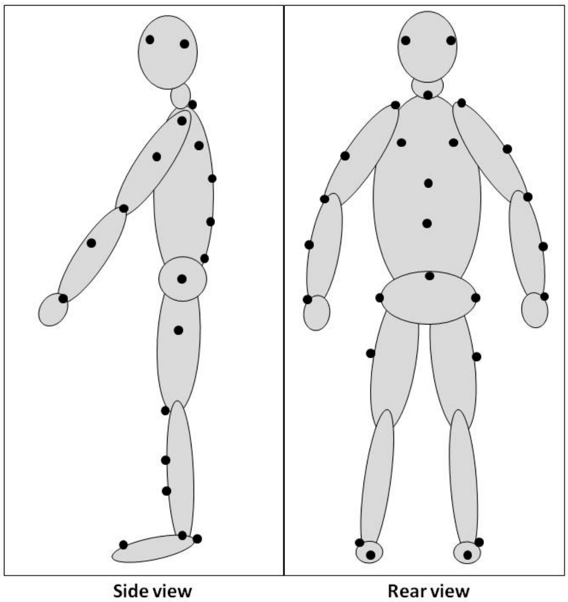

Figure 1. Position of attached markers on the subjects (left: sagittal plane, right: frontal plane)

Minimum and maximum hip, knee, ankle flexion as well as hip adduction were investigated. To make sure that the data were not influenced by acceleration as well as deceleration phases, rowing strokes in the middle of the rowing trial were used. Data were averaged over 10 rowing strokes and segment side. The stroke rate was not normalized because the point of interest was just range of motion. A Kolmogorov-Smirnov-Test was used to test the homogeneity of the data. Additionally, an independent samples t-test was performed to examine the effect of BMI on the aforementioned joint ranges of motion. The significance level was set at $p \leq 0.05$.

RESULTS: Two normal weight subjects (one female and one male) could not be included in the results because of missing data points. All data were homogenous ($p \geq 0,343$). Significant differences were found with respect to hip adduction (p=0,003) and abduction (p=0,045) between normal weight and overweight subjects. All other joint angles were not statistically different between the weight groups.

Table 3. Mean and standard deviation hip, knee and ankle flexion and hip adduction

	BMI_Group	N	Mean	Std. Deviation	t	df	p
hip flexion / extension	normal weight	8	52.9 / 105.7	13.5 / 8.9	-0.456 / -0.031		0.654 / 0.975
	over weight	10	56.1 / 106	15.8 / 17.1			
hip adduction / abduction	normal weight	8	-2.0/ 2.0	1.8 / 0.9	-3.452 / -2.175		0.003* / 0.045*
	over weight	10	0.3 / 4.9	1.0 / 3.7		16 /16	
knee flexion / extension	normal weight	8	-138.0 / -21.1	5.7 / 9.9	-1.318 / -1.150		0.206 / 0.267
	over weight	10	-132.9 / -16.8	9.6 / 5.9			
ankle flexion / extension	normal weight	8	-9.0 / 37.9	9.0 / 5.0	1.001 / - 0.499		0.332 / 0.625
	over weight	10	-13.0 / 39.9	8.5 / 8.6			

* Significant difference between normal and overweight subjects p<0.05.

DISCUSSION: The results revealed that the body shape does influence kinematic variables of rowing. The hip adduction and abduction were significantly different for the two weight groups indicating different movement strategies. More specifically, the overweight subjects demonstrated higher hip abduction and less hip adduction during the catch phase, possibly due to their body shape. No differences for the hip flexion and extension angles were found. The kinematic differences between the normal and overweight groups may provide insight into injury prevention.

Low back pain is a common injury for elite rowers (McNally & Seiler, 2005). The ability to produce a high flexion angle in the hip during the catch phase is related to the likelihood of developing low back pain in rowers (Soper et al., 2004). The increased risk for low back in rowers way be linked to kinematics, overtraining or skill level. It is known that in particular the hip flexion angle is closely related to skill level in rowing (Soper & Hume, 2004). Even though the subjects in this study had no or little previous experience in rowing on a rowing ergometer, their ability to perform the rowing technique might have influenced the results. However, the similarities in hip flexion angle between the normal and overweight subjects suggest that rowing may present similar risks for the groups.

The similar knee and hip flexion angles in the overweight subjects may indicate that the increased abduction angles were a compensation for the likely greater abdominal mass. However, fat distribution was currently not measured, thus reasons for the differing hip ab/adduction angles cannot be certain. Most elite rowers have a BMI over 25 due to their increased muscle mass (Skinner et al., 2010; Izquierdo-Gabarren et al., 2010). However, the participants in this study were volunteers with little or no previous experience. Therefore, an increased BMI due to increased muscle mass is unlikely. This presents a limitation in using BMI to assess body composition. These results indicate that there may be more differences in rowing technique for individuals with larger BMI (over 30) or higher percent body fat. Practical application to the differences in rowing kinematics between body sizes may involve changes to ergometer design.

In elite rowing sports the boat setups are variable. However, rowing ergometers are non-adjustable. The results of this study suggest that manipulation of the rowing ergometer (i.e. adjustable footrests, wider seats etc.) for different body shapes may be useful to remediate any kinematic variations and increase comfort during rowing. However, further studies (different skill levels, greater BMI variability etc.) are needed to gain insight into the differences in rowing kinematics between varying body types and how equipment manipulations effect these changes.

CONCLUSION: This study investigated rowing movement kinematics between normal weight and overweight subjects. Differences were found only for hip abduction and adduction angles. Manipulation of ergometer design may help limit these positions. The goal for future studies should be to investigate the kinematics between more widely varying body sizes (normal weight, overweight and obese) as well as the influence of different skill level and ergometer design on these groups.

REFERENCES:

Browning, R. C. & Kram, R. (2007). Effects of obesity on the biomechanics of walking at different speeds. *Medicine and Science in Sports and Exercise, 39*(9), 1632-1641.

Izquierdo-Gabarren M., González de Txabarri Expósito R., Sáez Sáez de Villarreal E., Izquierdo M. (2010). Physiological factors to predict on traditional rowing performance. *Journal of Applied Physiology*, 108(1), 83-92

Lai, P. P. K., Leung A. K. L., Li A. N. M., & Zhang M. (2008). Three-dimensional gait analysis of obese adults. *Clinical Biomechanics*, 23(1), 2-S6.

McNally, E., D. W. & Seiler S. (2005). Rowing injuries. *Seminars in Musculoskeletal Radiology, 9(4),* 379-395.

Sanada, K., Miyachi M., Tabata I., Suzuki K., Yamamoto K., Kawano H., Usui C.& Higuchi M. (2009). Differences in body composition and risk of lifestyle-related diseases between young and older male rowers. *Journal of Sports Sciences*, 27(10), 1027-1034.

Soper C & Hume P. A. (2004), Towards an ideal rowing technique for performance - The contributions from biomechanics. *Sports Medicine*, 34 (12), 425-448

Soper C., Reid D., Hume P. A. (2004), Reliable passive ankle range of motion measures correlate to ankle motion achieved during ergometer rowing. *Physical Therapy in Sport*, 5(2), 75-83

Skinner T. L., Jenkins D. G., Coombes J. S., Taaffe D. R., Leveritt M. D. (2010), Dose Response of Caffeine on 2000-m Rowing Performance. *Medicine and Science in Sports and Exercise*, 42(3), 571-576

Yoshiga, C. C. & Higuchi M. (2002). Heart rate is lower during ergometer rowing than during treadmill running. *European Journal* of *Applied Physiology*, 87(2), 97-100.

WHO expert consultation (2004). Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. *The Lancet*, 363(9403), 157-163.