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THE IMPACT OF BODY MASS AND SKILL LEVEL ON ROWING KINEMATICS

Chris Richter[1], Stephanie Hamilton[2] and Karen Roemer[2]

Health and Human Performance Department, Dublin City University, Dublin, Ireland[1]
Exercise Science, Health and Physical Education, Michigan Technological University, Houghton, Michigan, USA[2]

Rowing is a non-weight-bearing aerobic full body exercise, which is often recommended for weight loss programs. Previous studies demonstrated that Body Mass Index (BMI) is correlated with changes in the kinematics of humans. We extend this area of research to compare the effect of both BMI and skill-level on the kinematics of the lower extremities during rowing. Findings highlight differences such as knee flexion, knee internal rotation, hip extension, hip external rotation between normal weight and obese individuals. These findings suggest that injury risks are correlated to body type and previous skill level. This research indicates the need for adjustable setups for the rowing ergometer. This recommendation would not only increase comfort for all types of athletes, but reduce risks of injury and create the necessary conditions to accomplish a proper technique.

KEYWORDS: Motion analysis, body shape, injury prevention.

INTRODUCTION: Rowing combines the benefits of endurance exercise with resistance training, providing positive effects on both health and disease prevention. In previous work, it has been shown that actively participating in rowing reduces the risks of falls, limb disability and coronary artery diseases (Yoshiga & Higuchi, 2002). In addition, it has been shown that rowing can lower the risk of developing type 2 diabetes and hypertension, increase long chain fatty acid oxidation, metabolic rate, glycogenic control, lipoprotein profile, and fat-free mass (Sanada et al., 2009). Furthermore, rowing, as a non-weight bearing sport, results in lower loading on the joints compared with weight bearing activities (e.g. running, jumping) and may therefore decrease joint forces. Previous research in walking has shown that body shape affects kinematics and results in increasing joint forces (Browning et al., 2007; Lai et al., 2008). The aim of this study, therefore, is to analyze and compare rowing kinematics of normal weight, overweight, and obese individuals without previous rowing experience as well as normal weight individuals with previous rowing experience.

METHODS: The World Health Organization (WHO) Body Mass Index classifications were adopted to categorize body types in this work. Ten (five women & five men) each group normal weight, overweight and obese volunteers, with little or no previous rowing experience as well nine normal weight (five women, four men) volunteers with previous rowing experience (group normal weight skilled) were recruited. Detailed characteristics of the subjects are shown in Table 1. Exclusion criteria for participants included any past/current neurological or cardiovascular illness, or any pain that 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.
Body mass, height, and body composition were measured on each volunteer by a segmental body composition analyzer (Tanita, BC-418 Pro, Arlington Heights, USA), as well as segmental measurements of the whole body. A motion analysis system (Vicon, MX+, Oxford, United Kingdom) was used to collect the subject`s rowing kinematics. For the data acquisition process, subjects were asked to wear tight fitting non-reflective clothes. A custom designed marker set - of thirty four spherical reflective markers - was attached with double-faced adhesive tape (see Figure 1). In addition, 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 habituation with the rowing technique, subjects performed a short warm-up to practice the

technique at the desired stroke rate (23-25 strokes per minute). Subjects rowed at three different resistance levels (3, 5 and 7) for two minutes each and rested two minutes between the trials. The second minute of the rowing interval was captured by the Vicon system at 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. Minimum and maximum hip, knee, ankle flexion/extension, range of motion (ROM) as well as hip ab/adduction and knee and hip internal/external rotation were investigated. To make sure that the data were not influenced by acceleration as well as deceleration phases, only the first half of the captured data of every trial were used. Data was averaged over the first 12 rowing strokes and across left/right body side for those 12 strokes. The stroke rate was not normalized in this work, as the point of interest in this study is the range of motion.

Table 1
Subject information mean and standard deviation

	Normal weight	Over weight	Obese	Normal weight skilled
Number of Subjects	10 (5 f, 5 m)	10 (5 f, 5 m)	10 (5 f, 5 m)	9 (5 f, 4 m)
Age (year)	27.4 ± 7.21	24.1 ± 5.99	26.0 ± 3.13	23.9 ± 4.34
Height (m)	1.74 ± 0.77	1.71 ± 0.88	1.70 ± 0.88	1.78 ± 0.94
Weight (kg)	66.4 ± 9.22	78.4 ± 9.27	103.2 ± 22.64	70.1 ± 8.15
BMI (kg/m²)	21.8 ± 1.59	26.6 ± 1.33	35.4 ± 4.69	21.3 ± 1.21

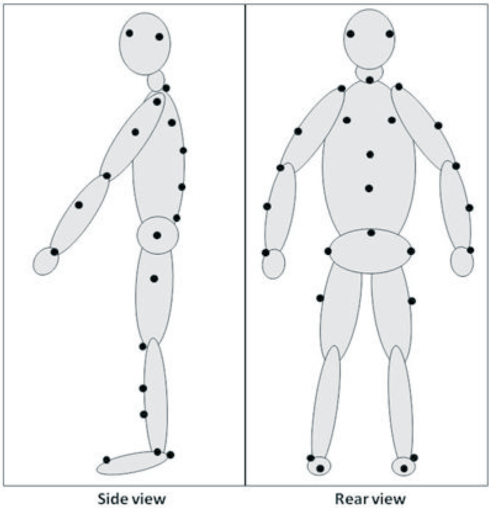

Figure 1: Position of attached markers on the subjects (left: sagittal plane, right: frontal plane).

Before the statistical analysis, all data was tested for homogeneity and normal distribution. To examine the effect of BMI on the joint ranges of motion, we performed a repeated measure ANOVA (pair-wise comparisons Bonferroni's correction were performed to assess specific differences between the groups) if the data was both homogeneous and its distribution was normal, or by non-parametric tests (multiple comparisons by Mann-Whitney Test) if otherwise. The significance level for all statistical analysis was set at $\alpha = 0.05$ except for the non-parametric test ($\alpha = 0.008$). The α level for non-parametric tests was divided by the number of comparison to avoid the type I error.

RESULTS: In our experiments, all data had a normal distribution (p > 0.05) and homogeneity in variance (p > 0.05), except for knee flexion (p < 0.05). Table 2 shows the statistical data obtained in detail. Differences in body parameters were found for body weight, BMI and body fat regarding BMI-classification while no differences were found between the tested resistance levels. Significant differences in knee flexion, internal rotation, hip extension, external rotation, abduction and adduction were found between normal weight and obese subjects. Additionally, knee internal rotation and ROM, hip flexion, external rotation, abduction and adduction were significantly different in the normal weight skilled compared to the obese group. No differences were found in physical properties such as age, height, and segment length between the investigated groups. Finally, no differences were found between the groups in normal BMI range regarding physical properties and kinematics.

Table 2
Mean, standard deviation and p-values of factors with statistical difference between groups

		body properties		
		normal BMI groups	vs. obese group	p-value
body weight		68.3 ± 8.7	103.2 ± 22.6	p = 0.001
BMI		21.6 ± 1.4	35.4 ± 4.7	p = 0.001
body fat - leg		7.4 ± 3.8	13.0 ± 2.2	p = 0.001
body fat – torso		7.2 ± 3.8	18.0 ± 4.3	p = 0.001
		Kinematics		
	rowing phase	Group normal weight	vs. group obese	p-value
knee flexion	- catch	-139.1 ± 4.8	-123.0 ± 14.4	p = 0.003
hip extension	- finish	57.1 ± 12.1	35.6 ± 9.8	p = 0.009
		Group normal weight skilled	vs. group obese	
knee ROM	- full stroke	123.0 ± 3.8	109.0 ± 16.2	p = 0.047
hip flexion	- catch	112.7 ± 15.8	88.1 ± 14.2	p = 0.003
		normal BMI groups	vs. group obese	
hip abduction	- catch	-3.2 ± 1.2	-10.3 ± 8.1	p = 0.004
hip adduction	- finish	1.4 ± 1.4	-1.7 ± 1.8	p = 0.001
knee internal rotation	- catch	-6.88 ± 10.8	-8.87 ± 7.9	p = 0.001
external hip rotation	- catch	2.74 ± 8.9	12.86 ± 7.8	p = 0.001

DISCUSSION: Results revealed that BMI influences the kinematic variables of rowing. Only the obese group displayed statistical differences rowing kinematics compared to other groups. The different movement strategies in the catch and finish phase are likely produced by the greater fat mass in the lower extremities. Three possible reasons can account for the different movement strategies of the obese subjects:

a) in order to compensate for the greater abdominal mass, obese subjects increase hip abduction and adduction angles,
b) greater fat mass in the shank and thigh produce a restriction of knee flexion in the catch position,
c) the different movements may provide greater comfort for obese subjects.

A possible explanation for the greater hip extension could be that obese subjects are not able to decelerate the trunk energy in the same ROM compared to normal weight athletes at the finish position. The difference in hip abduction, rotation and knee rotation may lead to increased loads in the knee joint of obese individuals. Since knee osteoarthritis is a common affliction for obese individuals (Lai et al., 2008), rowing could have a negative impact to symptoms. However, arriving at a definite conclusion without kinetic data is not possible.

Rowing experience also affected movement strategies. Skilled rowers had slightly increased hip flexion (catch phase) and knee extension angles (finish phase). These changes are likely related to performance factors and allowed athletes to increase the stroke range. Hase et al. (2004) also found a small statistical influence between rowing kinematics (increase in knee extension, less trunk movement and less variance in motion) produced by skilled and unskilled rowers with similar physical properties. Changes in kinematics could produce different risks of injury in rowing. Low back pain is a common injury for elite rowers (McNally & Seiler, 2005) and difference in kinematics may increase propensity for such pain. Soper & Hume (2004) suggest that a flexion of the lumbar spine increases the risk of low back pain. Therefore, an increase in hip flexion would likely decrease flexion of the lumbar spine and should consequently lower this risk of low back pain. These results could indicate the possible danger of an increasing risk for low back pain for the obese group. However, it is not yet known if the increased risk for low back pain in rowers may be linked to kinematics, overtraining or overloading. Nevertheless, the variation in hip flexion angle between the normal weight (skilled/unskilled), overweight, and obese subjects suggests that rowing may present different injury risks for the investigated groups. A practical application of the differences in rowing kinematics between body shapes may involve changes to ergometer design. Unlike elite rowing boats, where the setup is variable, the rowing ergometer is non-adjustable. The results of this study suggest that manipulation of the rowing ergometer for different body shapes may be useful to remediate any kinematic variations (i.e. adjustable footrests, wider seats, incline seats etc.) and increase comfort during rowing. Nevertheless, further studies are needed to gain insight into the differences in rowing kinematics and how equipment manipulations affect these changes.

CONCLUSION: Body shape and rowing experience influence rowing kinematics and may produce different risks for low back pain. Adjustable setups of the rowing ergometer may decrease injury risks and could increase comfort for obese. Increasing rowing comfort for obese individuals may also lead to an increase in exercise participation.

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