# THE EFFECT OF MEASUREMENT TECHNIQUE AND LOAD ON LOWER LIMB KINEMATIC'S IN CYCLE ERGOMETRY

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## INTRODUCTION

Many studies involving cycle ergometry often provide a description of lower limb kinematics. This description has been used to provide information regarding: body position and configuration that maximizes aerobic energy expenditure (Nordeen 1976, Nordeen-Snyder 1977, and Too 1990,1991); optimal seat *lo* pedal distance for anaerobic and aerobic work (Gregor 1676.199 I, Hamley 1967, Nordeen-Snyder 1977); and simulations of lower limb kinematics (Gregor 1976). However, joint angle measurements *are* often done statically (Too IYYI), and may not reflect the actual joint kinematics during the assigned task. This is a possible limitation of studies involving a description of lower limb kinematics. and presents a specific question that needs lo be addressed

Do measurements of lower limb joint angles vary when determined with different measurement techniques under various conditions? Based on the tension-length curve, a muscle will generate it's largest force/tension at 100% of (or slightly greater than) its resting length. As the muscle length deviates from resting length, and/or with the onset of fatigue, force/tension production decreases. Compensation for a decrement in force may result in joint angle differences when measured statically, dynamically, and/or with different conditions of resistance and fatigue. It may be important to measure joint angles during the performance of assigned test conditions. Therefore, the purpose of this study was to determine whether joint kinematics change with different measurement techniques, wnditions of loading, and with fatigue.

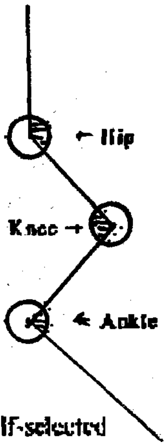
## METHODOLOGY

Nine males with recreational cycling experience participated in this study. Informed consent and the following anthropometric measurements were obtained for the right leg total leg length and lower leg length. Average age, height, and weight were 26.9 years (S.D.=3.11), 180.4 cm (S.D.=8.01), and 77.37 kg (S.D.=6.82), respectively. A Monarch 814E cyck ergometer with a basket, plate-loaded resistance mechanism was used in this study. Seat to pedal distance was adjusted to 109% of each subject's total leg length as measured from the symphysis pubis to the *pound* (±1 cm) (Hamley 1967). Pedal toeclips were worn; and each subject's upper body was kept perpendicular to the ground.

Four joint angle measurement conditions--goniometer, unloaded, loaded-non fatigued, and loaded-fatigued--were examined for three joints--hip, knee, and ankle (Figure 1). In the first condition, the maximum and minimum joint angles were determined statically with a hand-held goniometer. In the three other test wnditions, joint angles were determined whh an Ariel Performance Analysis

System (APAS). A video camera positioned perpendicular to the median plane of the subject pedalling on the ergometer was used to record[1] minimum and maximum joint angles in the unloaded, loaded-non fatigued, and loaded-fatigued conditions. Digitizing points were attached to the right side of the subjects at the following anatomical sites distal end of the foot, lateral malleolus, axis of rotation of the knee, greater trochanter of the femur, and a point attached to a plumb line positioned to intersect the marking on the greater trochanter, located on the deltoid as viewed through the camera.

**Figure 1: Joint Angle Definitions**



During the unloaded condition the subject pedaled at a self-selected cadence and one pedal revolution was selected for digitizing The Wingate Anaerobic Cycling Test (Lamb, 1984) was used to induce the loaded-non fatigued and loaded-fatigued joint angles which were defined by the maximum minimum power outputs, respectively Power output was determined by an SMI Power Program[2]. Subjects were instructed to warm-up and encouraged to cycle on the ergometer with maximal, intermittent bursts 2-4 seconds in duration. To initiate the test, the subject was instructed to pedal as fast as possible: during which, 85gm/kg of the subject's body mass (5 0 joules/pedal rev/kg BM) was instantaneously applied. The subject was verbally motivated to continue to pedal as fast as possible for the duration of the 30-second test. After completion of the test, the subject was encouraged to continue pedaling with reduced resistance to facilitate recovery. Analysis of the loaded-non fatigued and loaded-fatigued joint angles was accomplished by synchronizing the video with the power output. The pedal revolution occurring at the third second of the maximum and minimum 5-second power intervals, as indicated by the SMI Power Program, was used for digitizing purposes.

## RESULTS

Joint kinematic changes with different measurement techniques, conditions of loading, and with fatigue are presented in Table 1 Doubly multivariate repeated measures analysis of variance (DB MANOVA's) were used to compare joint angles across all conditions. Significant differences were found in the hip joint angles with $F(6,46) = 3.35$, $p = 0.013$ (Wilks' lambda); in the knee joint angles with $F(6,46) = 4.04$, $p = 0.002$ (Wilks' lambda), and in the joint angles of the ankle with $F(6,46)$ 7 98, $p = 0.000$ (Wilks' lambda) Independent Separate MANOVA's were used to compare the minimum and maximum joint angle measurements of the hip, knee, and ankle Significant differences, $p<0.05$, were

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[1] Filming speed was 100 frames per second.

[2] Sports Medicine Industries, Inc., version 1.02a, © 1992

found for the maximum angle of the hip with F(3,24) = 6.62; the knee with F(3,24) = 6.06; and the ankle with F(3,24) 8.63, and for the minimum angle of the ankle with F(3,24) 6.79. T-tests (Scheffe) were used to determine where significant differences ($p < 0.05$) occurred and are presented in Table 2.

| | Joint Angle (deg) | | | | | |
|---|---|---|---|---|---|---|
| | Hip Min | Hip Max | Knee Min | Knee Max | Ankle Min | Ankle Max |
| Goniometer | | | | | | |
| mean | 1110 | 151.833 | 74.667 | 149.444c | 97.778e | 122.333g |
| std. dev. | 5.329 | 4.916 | 5.568 | 8.033 | 9.947 | 10.344 |
| Unloaded | | | | | | |
| mean | 112133 | 150.917ab | 72.289 | 142.089cd | 100.056 | 127.889 |
| std. dev. | 6.41 | 8.963 | 4.655 | 11.872 | 10.018 | 6.885 |
| Loaded-NF | | | | | | |
| mean | 112.183 | 158.233a | 73.322 | 147.1 | 106.944ef | 129.122 |
| std. dev. | 5.26 | 8.287 | 4.488 | 9.584 | 9.105 | 7.026 |
| Loaded-Fat. | | | | | | |
| mean | 11545 | 158.067b | 75.332 | 147.817d | 94.078f | 135.511g |
| std. dev. | 4.793 | 9.331 | 4.117 | 11.117 | 6.706 | 7.672 |

Table 1: Hip, Knee, Ankle Angles with Four Conditions
letters a-g indicates pairs of conditions with significant difference, $p < 0.05$

| Joint Angle-Condition | Goniometer | Unloaded | Loaded-Non Fatigued | Loaded-Fatigued |
|---|---|---|---|---|
| Hip Max--Unloaded | | | | |
| Knee Max--Unloaded | ** | | | ** |
| Ankle Min--Loaded-Non Fatigued | ** | | | ** |
| Ankle Max--Goniometer | | | | ** |

Table 2
** Significant differences between conditions, $p < 0.05$

## DISCUSSION

Significant differences found when using different measurement techniques--goniometer vs. videotape--occurred in the maximum angle measurements of the knee and both the minimum and maximum angle measurements of the ankle. This may be attributed to the following: (1) measurement error and variability when

## CONCLUSIONS

DBMANOVA's and post-hoc tests revealed significant differences ($p<0.05$) in the (1) minimum ankle angle; and (2) maximum angle of the hip, knee, and ankle when determined with different measurement techniques (goniometer vs videotape) and in different test conditions (loaded vs unloaded, fatigue vs non-fatigue). It is concluded that different measurement techniques and conditions of loading will result in different hip, knee, and ankle joint kinematics. Whether joint angles should be measured during the actual test condition would be dependent on the nature of the question and the degree of measurement accuracy required.

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