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FORMULATING PREDICTIVE MODELS FOR RE-DESIGN OF ROWING SIMULATOR

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ABSTRACT

Aim of this study was to re-design the rowing simulator developed earlier. The simulator suffered from major drawbacks in terms of correlating the output variables (forces) with body discomforts towards enhanced performance. Therefore, the present study was undertaken to identify the major discomforts of Young Indian Rower, to associate them with the forces exerted by rowers through predictive models and modify the rowing simulator. The study was carried out on one hundred and eight young Indian rowers who participated in both State and National Level Rowing Championship. A self-reported questionnaire was administered. Data analysis was carried out through factor analysis followed by ordinal regression to formulate predictive models. Based on the results, suitable modification on the pre- rowing simulator model was carried out. An experiment was performed to validate the rowing simulator. The results showed that overall experience of the rowing simulator was similar compared to on water rowing.

Key words: Rower, Simulation, regression, Performance, Prediction

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1. INTRODUCTION

Rowing demands high muscular force, motor skills and intensive training sessions [1]. It has been reported that in order to attain competitive level, rigorous training sessions are required. Training sessions conducted by professional rowers using appropriate training equipment impact sports performance [2]. Rowing in natural settings is not possible throughout the year mainly due to adverse climatic conditions. Because of this on water rowing or simulator rowing becomes expensive and inaccessible. Therefore, various attempts have been continuously made to develop simulators which provide kinematics of movements and forces similar to on water rowing [3-5]. Hawkins developed a dry-land rowing system to provide quantitative information about the athlete's kinetics and kinematics during training sessions [6]. However, there were errors in measuring Kinematic and kinetic data at different planes. Zitzewitz et al. developed a Real-time rowing simulator with multimodal feedback for single skull [7]. Nevertheless, there were significant errors in evaluating oar handle force. Grigas developed a device to measure the variation of the strength of magnetic field that affects the magnetorheological fluid circulating in the device, ensuring a variation of the resistance force on the oar handle adequate for the resistance that occurs during a real boat rowing [2]. Mandar et al. attempted to design a rowing simulator for Young Indian Rowers which could quantify the major biomechanical forces including seat, oar handle and foot stretcher force [8]. The design faced major drawbacks in terms of correlating the output variables (forces) with body discomforts towards enhanced performance. Literature suggests that a lack of consensus exists between the relationship between force profile characteristics and rowing performance [9]. Therefore, the present study was undertaken to identify the major discomforts of Young Indian Rower, to associate them with the forces exerted by rowers through predictive models and modify the pre-developed rowing simulator model for enhanced performance.

2. MATERIALS & EXPERIMENTAL PROCEDURES

The entire study was carried out into two phases. Phase I was based on self-reported questionnaire study and Phase II was an experiment to validate the modified rowing simulator.

2.1. Participants

One hundred and eight rowers (seventy-one males and thirty-seven females) of age group 16 to 25 years were considered for the study. Data from one hundred and eight young Indian rowers from various State Level Rowing Competition across Maharashtra was collected for this study. Exclusion criteria were as follows: history of serious injury in the past and recent illness from past one month. Inclusion criteria was minimum one year of experience in rowing. Signed informed consent was obtained from each subject. The study was approved by Institutional Ethics Committee, Pune, India.

2.2. Measures

A detailed questionnaire was administered, based on literature study to identify prone areas of discomfort on the body. The visual image of the body was shown which was segmented into various body parts segregated into right and left. The body parts include neck, shoulders, upper back, mid back, lower back, buttock, thighs, knees, ankles, calves, feet, forearms, upper arms, elbows and wrists. Rowers were asked to grade the discomfort on Likert scale of 0 to 5 where 0 implies no discomfort and 5 implies excessive discomfort. Based on the feedback an experiment was carried out to modify the pre-rowing boat.

2.3. Procedures

The rowers were explained about the purpose of the study and briefed about the context of various questions in the questionnaire. The internal consistency of questionnaire was assessed through Cronbach Alpha. The Cronbach Alpha value for the questionnaire was found to be 0.88 which is within the good range [10]. Following were the demographic details of the selected rowers. The mean height was 171.46 (± 10.10) cms and the mean weight was 64.89

(± 10.90) kgs. The mean years of experience was 2.5(± 1.98) years. Mean regular hours of practice was 3.33(± 1.60) hrs. The mean best performance time for rowing was 1.56(±0.34) minutes.

2.4. Analysis

Statistical analysis was carried by SPSS 20. Factor analysis was carried out to determine the factors which were based on summarizing the total variance. FA reduces the dimensionality of a data set consisting of a large number of interrelated variables, while retaining as much as possible of the variation present in the data set. FA of only those body parts were considered which showed moderate and above responses on scale of 0 to 5. Therefore, the body parts included for factor analysis were shoulders, mid back, lower back, forearm, buttock, thighs and calves. Since factor loading for mid back was less than 0.05, it was removed from further analysis. Further, regression was carried out on the components to develop predictive model to find association between major risk factors and rowing parameters. Based on the findings, modified design specifications for simulator were decided. An attempt was made to re-develop the pre- simulator which gives an experience for row boat. Further, an experiment was carried out to validate the rowing simulator model.

2.5. Modification & Validation of Rowing Simulator

The pre- rowing simulator suffered from major drawbacks in terms of correlating the output variables (forces) with body discomforts towards enhanced performance. It also had various drawbacks related to mechanisms and adjustments for addressing rowers from various body dimensions. The blower was unable to generate the necessary force required for rowing resulting in inability to get variations in drag required to simulate it to different rowing conditions. Height of oar handle with reference to rowers sitting position was inappropriate.

2.5.1. Modification

The findings from questionnaire of present study established association of body parts with output variables (force). The extracted factors (body parts) through FA were responsible to generate various forces like oar handle force, foot stretcher force, seat force, at the time of rowing and contribute to the performance of a rower. Changes in some mechanisms and fine tuning of mechanisms were done in order to achieve minimum friction in all the moving parts. The flywheel assembly of simulator was replaced by two bought out Concept 2 ergometer flywheel assemblies to get the precise variations in drag. Subsequently, adjustments in inbound distance with subject to rower body dimensions were made. The overlap distance for the skull handles when both the arms come closer to the chest was also adjusted to suit the Indian rowers. In order to provide adequate flexibility and rotational movement to the oar handle at the time of release, alterations were made at the joint of oar towards the pin and oarlock end.

2.5.2. Experiment for Validation

A young Indian rower of 18 years of age, with height 171.5 cm and weight 72 kg was contacted for the study. He had actively participated in National level rowing Competition and had no history of any injury in the past. Before few days of the experiment, the subject was asked to get acquainted with the rowing simulator. The subject was asked to Sign informed consent form. On the day of experiment fifteen minutes rest was given before the test session to achieve resting state. Subsequently, the subject was asked to do routine warm up exercises. The subject was asked to row on the simulator with stroke rate of 20strokes / minutes for distance of 500 metres (Figure 1). The output variables: seat force, foot stretcher force and oar handle force was captured. The data recorded from data logger.

3. RESULTS

Factor Analysis

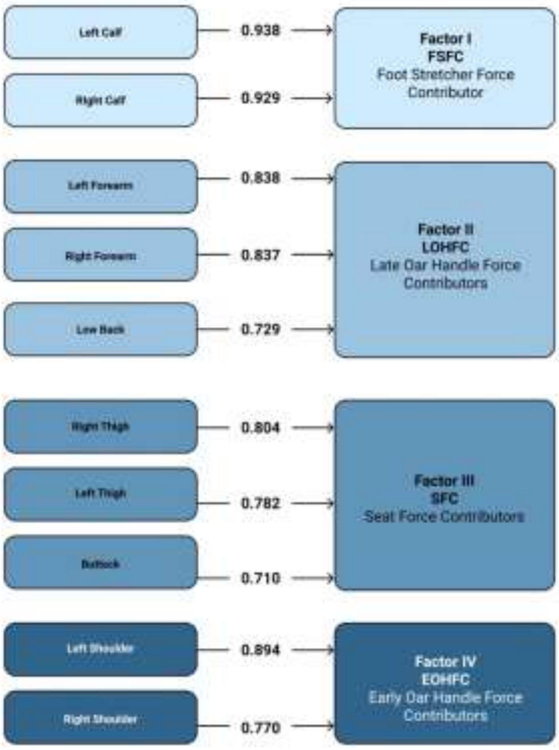

Figure 1 Representing Factor Loading & factors extracted

Figure 1 depicts the four major factors extracted through FA. The naming of factors was carried out on the basis of biomechanical parameters of rowing. Factor 1 was with the highest factor loading on both calves which was named as Foot Stretcher Force Contributor (FSFC). Factor 2 comprised of forearm and low back which was named as Late Oar Handle Force Contributor (LOHFC). Factor 3 had loadings on thighs and buttock which was named as Seat Force contributor (SFC). Factor 4 comprised of both shoulders which was named as Early Oar Handle Force Contributor (EOHFC).

Model 1 showed association between best performance time and FSFC. Model 2 showed association between long practice session SFC and FSFC. Model 3 showed association between insufficient rest with FSFC. Model 4 showed association between sudden performance increase SFC and FSFC. Model 5 showed association between poor posture SFC and FSFC. Model 6 showed association between lack of fitness and flexibility with SFC and FSFC. Model 7 showed association between technical flaws with SFC and FSFC. Model 8 showed association between touring with SFC. Model 9 showed association between stress with SFC and FSFC (Figure 2). Figure 3 and Figure 4 are results from experiment conducted to validate the redesign of rowing simulator. The results of seat force, handle force and foot stretcher force are depicted.

Integrated Models

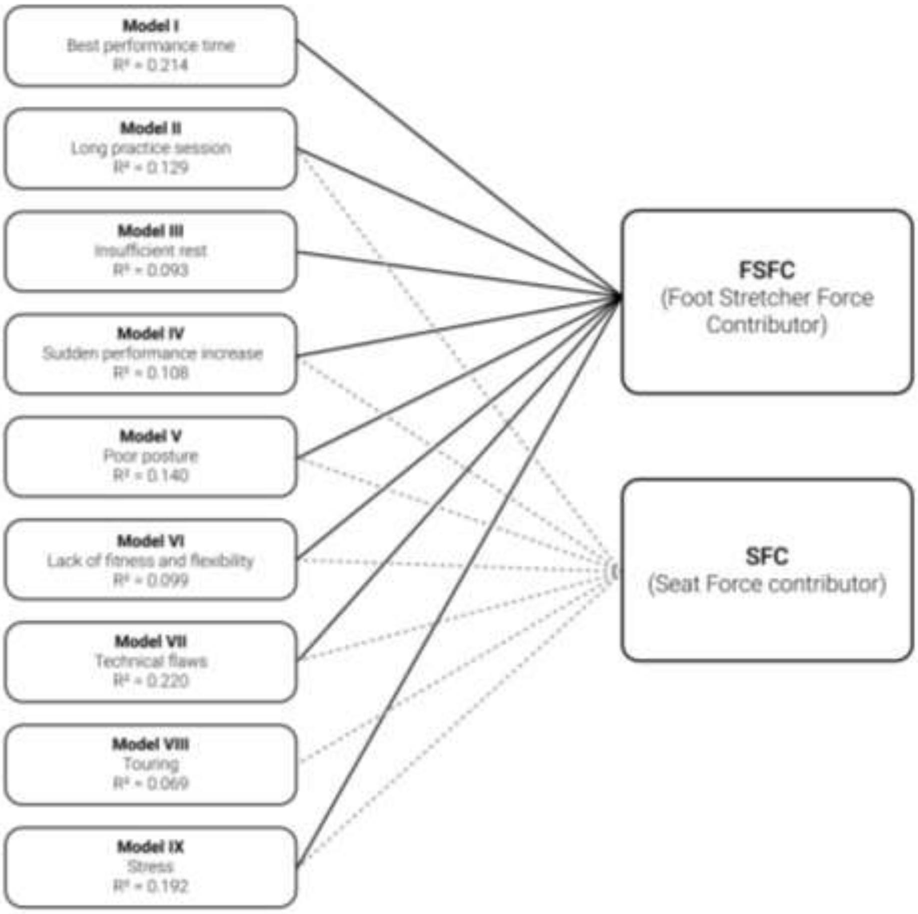

Figure 2 Representing Predictive Models

Experiment on Redesigned Rowing Simulator

Figure 3 A subject performing the experiment of the re-designed rowing simulator

Experimental Analysis

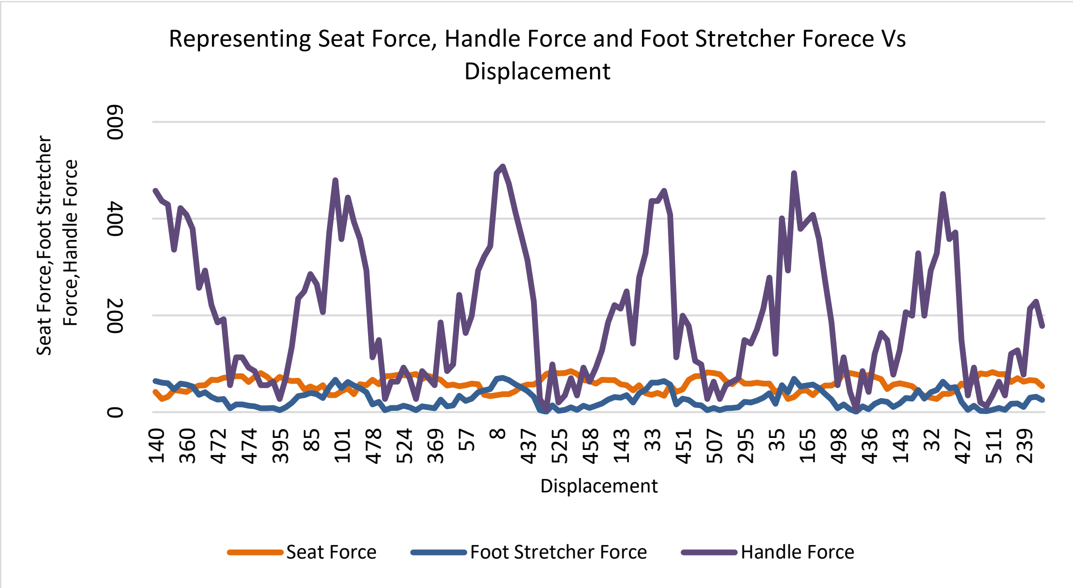

Figure 4 Graph representing Forces v/s Displacement

4. DISCUSSIONS

The study identifies prone areas of discomforts. It was found that the body parts with highest factor loadings were right calf, left calf, right forearm, left forearm, lower back, right thigh, left thigh, buttock, right shoulder and left shoulder. Our findings corroborated with previous studies. It has been found that rowing required prolonged oar handling in symmetrical and synchronised manner, which made them prone to forearm injuries [11]. The repetitive activity caused shoulder complaints as a common phenomenon among rowers [12]. Literature indicated that low back was major area of concern among rowers [13-14]. Wilson et al. took participants who were international rowers belonging to elite class and identified major areas of discomfort [15]. The major areas of complains were higher in lower back, knee, cervical spine while shoulder, thighs and calves were found in lower range. The differences in the value with present study may be due to different age groups. The present study involved Young Indian Rowers with age group of 16 to 25, besides; studies have revealed that young sportsperson is more prone to discomforts than young.

From the results of Figure 1 highest factor loadings were computed. Four factors were extracted and were named on the basis of biomechanical parameters. Factor 1 constituted of Calves, hence was named as Foot Stretcher Force Contributor (FSFC). Studies have showed that energy expenditure of lower body part is more than upper body part [16]. Moreover, studies have also indicated that foot stretcher positioning was determined by lower leg biomechanics. Among the different muscles involved in lower limb it has been found that calf muscle recruits' maximum strength [17]. Consequently, Factor 1 was named as Foot Stretcher Force Contributor.

Factor 2 constituted of forearm and low back, hence was named as Late Handle Force Contributor (LOHFC). Studies have revealed that extended elbows/forearms contribute in creating greater force on oar handle [18]. While rowing, the rower turns prone to low back injuries due to the amount of time a rower spends in a flexed position, the number of rowing stroke cycles completed, and the forces on the body during the rowing stroke. Thus, the involvement of forearm and low back was evident in generating oar handle force while completing the catch, hence it was named as Late Oar Handle Force Contributor (LOHFC).

Factor 3 consisted of thighs and buttock. Soest and Hofmijster conducted study on 11 rowers to determine if the contact of buttock with seat improves rower's performance. It was found that that strapping a rower's pelvis to the sliding seat allows more vigorous execution of the stroke phases, resulting in a substantial improvement in performance during the start of ergometer rowing [19]. Thigh muscles also contributed in creating pressure on seat. Hence it was named as Seat Fore Contributor. Factor 4 consisted of shoulders. Studies have indicated that shoulder muscles were involved in early drive phase [18], hence it was named as Early Oar Handle Force Contributor (EOHFC). Based on the findings of factor analysis, further Ordinal Regression was carried out on the extracted factors as independent variables.

Model 1 signified best performance time as dependent on FSFC (both calves) (Model I). Model 2 signified long practice session as dependent on FSFC (both calves) and SFC (both thighs and buttock) (Model II). Model 3 signified insufficient rest as dependent on FSFC (both calves) (Model III). Model 4 signified sudden performance increase as dependent on FSFC (both calves) and SFC (both thighs and buttock) (Model IV). Model 5 signified poor posture as dependent on FSFC (both calves) and SFC (both thighs and buttock) (Model V). Model 6 signified lack of fitness and flexibility as dependent on FSFC (both calves) and SFC (both thighs and buttock) (Model VI). Model 7 signified technical flaws as dependent on FSFC (both calves) and SFC (both thighs and buttock) (Model VII). Model 8 signified touring as dependent on SFC (both thighs and buttock) (Model VIII). Model 9 signified stress as dependent on FSFC (both calves) and SFC (both thighs and buttock) (Model IX). It can be said that the risk factors are majorly dependent on FSFC (both calves) and SFC (both thigh and buttock). This constitutes primarily lower body parts. Literature postulated that lower body parts are contributor towards seat force and foot stretcher force. The rowers act as linkage for generating foot stretcher force and oar handle force [3]. Nevertheless, performance of rowers is dependent on rower's ability to develop larger foot stretcher forces. Studies have postulated that lower body has significant impact on rowing compared to upper body [16]. Present study through different models also substantiated with literature postulating that lower body had impact on rowers influencing performance. Based on the findings where impact of lower body on performance was postulated, suitable modifications were made on rowing simulator model.

Rauter developed a virtual environment for supporting training and the identification of performance indices based on models taken from experts using heuristics of machine learning techniques [20]. Hawkins constructed a dry-land rowing system with immediate feedback mechanism of rower's joint kinematics, pulling force and pulling power [6]. However, the rowing system could not gather effective data due to slippage of goniometers and moreover all the three important biomechanical forces were not captured. It has been found that attempts fail due to lag time difference towards modification of performances and also due to inability to gather appropriate output variables (seat force, oar handle force and foot stretcher force) correctly. Literature reported that three major forces contribute in rowing namely, seat force, oar handle force and foot stretcher force. Kleshnev conducted a study to quantify the forces exerted by various body parts and found that on average only 52.8% of total rowing power was applied at the handle and 47.2% was applied at the foot stretcher. Legs execute 45.2% of total rowing power; trunk does 32.2% and arms do 22.6% and showed that of all the three forces, 45 % is foot stretcher force, 32% was the synchronised effect of these forces helps in completing the phases of rowing cycle [5]. The pre- rowing simulator was unable to generate adequate force as aforesaid output variables. Therefore, essential forces from respective body parts were not generated appropriately. The essential force generation from each body part is associated with force / strength of respective body part which in turn escalates stress leading to discomfort. The findings from the questionnaire showed that left side has more discomforts than right ones which substantiates asymmetrical force generation

[21] among rowers. Since the predictive models establishes association between body parts discomforts and output variables (forces). After suitable modification on pre- rowing simulator validation was carried out and results of experiment showed promising results (Figure 3). The results of the experiment showed maximum seat, foot stretcher and oar handle forces of three different phases (Figure 4). Hence, it was found that values generated were appropriate. Feedback form the subject showed that the overall experience of rowing simulator was equal to on water rowing experience.

5. CONCLUSIONS

The present study was undertaken to identify the major discomforts of Young Indian Rower, to associate them with the forces exerted by rowers through predictive models and modify the rowing simulator for enhanced performance. The results of questionnaire helped in modifying the pre- rowing simulator. Inferences drawn from the experiment indicated variation of seat, foot stretcher and oar handle forces at different phases. Nonetheless, oar handle force value captured was average value of force exerted by both hands. However, the study needs to be carried out on larger sample size comparing with the data gathered from on water boat experience.

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