Optimization for Lunar Mission Training Scheme Based on AnyBody Software

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Abstract. Since majority of the lunar missions are accomplished by the upper limbs according to literature analysis, it is necessary for us to focus on studying astronauts' upper limb movement. This paper aims at studying the training schemes for the lunar mission through computer simulation with AnyBody software. Knocking, one of the typical lunar missions was selected as the study subject. Based on the verification experiment of earth's gravity level, the model of AnyBody software can be used to simulate lunar missions. An optimization of knocking move were provided by our AnyBody model.

Keywords: simulation, lunar mission training, optimization.

1 Introduction

Lunar exploration is one of the most significant objects in the near future. Comprehending the characteristics of human movement under the lunar environment is necessary to the early training and the success of lunar missions. The method of simulating calculation used in the aerospace field provides details about astronauts' moves during exploration, and it enables to shorten training period and improve efficiency. Traditional method of training task selection not only involves too much experiment but also is strongly affected by researchers' perspective. Compared to traditional method, simulating calculation can provide much more reliable guideline about training program. So the method of simulating calculation has many advantages over traditional methods. Documents showed that models applied to astronaut activity simulation were mostly physical models[1-3],such as the stick model [4], the spherical space toroidal model [5], the entity split model [6], the surface model [7] and so on. However, these models do not consider astronauts' physiological features, and have many limitations in evaluating safety and comfort.

AnyBody is the software that can excellently simulate human ergonomics and analyze biomechanics, and it considers human skeletal muscle system well. By

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importing integral human skeleton and muscles model and setting initial parameters, the software can automatically calculate each human bone and muscle's condition. Currently, this software is wildly applied in the field of ergonomics and biomechanics, such as analysis of a femoral-fracture fixation-plate implant [8], musculoskeletal computational analysis of the influence of car-seat design [9], ergonomic analysis of manual materials handling tasks [10], musculoskeletal model of the mandible [11] and so on.

Literature analysis results showed that during the lunar exploration, most tasks are related to upper limb [12]. This paper focuses on computer simulation that based on AnyBody. A typical move, knock, is chosen as our analysis object, because knock is one of the most frequent moves during lunar exploration. And later, an optimum training scheme is acquired according our simulation.

2 Knocking Modeling and Simulation

Musculoskeletal human-body model discussed in the study was built in the AnyBody Modeling System. A specific model environment was constructed by importing parameters including acceleration of gravity, initial posture and kinematics data. Then the model was driven to move as pre-set. The model was built under earthly environment. Setting the gravity of the model to be the earthly gravity ($g=-9.81m/s^2$). The initial posture is standing naturally. Keep the trunk straight, the left arm fall naturally and the right arm completing the knocking move. Initially, the right arm flexed 40° (Namely, the included angle of the right upper arm and vertical direction is 40°), and the fore arm flexed 110° on that basis(Namely, the included angle of the fore arm and the horizontal direction is 60°). A hammer weighs 0.64kg was grabbed by the right hand. The countertorque was added to the right wrist to imitate the state of wearing spacesuit. Then the kinematics parameters were imported into the model to motive the right arm to complete the knocking move. The right fore arm knocked down from initial posture to the horizontal direction with the upper arm nearly keeping still. The simulation model was used to calculate the following six schemes. Knocking movement was performed under the angular velocity of 60°/s and 80°/s separately with the right shoulder joint adducting 15°(Hereinafter referred to as Add 15°),adducting 0°(Add 0°)and abducting 15°(Abd 0°).

The simulation model under the lunar environment was set afterwards. Setting the gravity of the model to be the lunar gravity ($g=-1.622m/s^2$).The initial posture and knocking move were identical with the earth's model. Fifteen lunar schemes were calculated by the lunar model. Knocking movement was performed under the angular velocity of 60°/s, 70°/s and 80°/s with the right shoulder joint adducting 15°,10°(Hereinafter referred to as Add 10°),5°(Add 5°),0°and abducting 5°(Abd 5°).

The AnyBody software showed max muscle activity and muscle force when each scheme calculation was finished. The muscle force of deltoideus (Hereinafter referred to as Del), biceps brachii (Bi), triceps brachii (Tri) and trapezius (Tra) was selected to be analyzed among the large results. The study chose the average value of muscle force to be the analysis index.

3 Model Verification

3.1 Testing Program

To verify the validity of the results got by AnyBody software, verification experiment under the earthly environment was performed. The four muscles (Del, Tri, Bi, Tra) which were considered on the AnyBody software were selected to be the study objects. Surface electromyography (SEMG) and subjective assessment were the indices in the verification experiment.

Subjects. 10 young males that coincide with AnyBody model's body size such as height and weight were selected for the verification experiment on the premise of not informed anything about the simulation results. All the subjects were in good health, without muscle fatigue, taking no strenuous exercise 24hours before and getting used of the experimental requirement.

Sports Load, Signal Acquisition and Processing. Subjects adopted standing posture which the trunk remained straight. The angle between the right fore arm and horizontal direction was 60^{o}, while the angle between the right upper arm and the vertical direction was 40^{o}. The right hand which gripped hammer was tied on the countertorque producing equipment. The left arm falls naturally. Knocking at the position and the angular velocity as the schemes set in the earthly simulation model. Stable rap rhythm was provided by Cherub WSM330 mechanical metronome; countertorque was offered by BTE PRIMUSRS; SEMG was acquired by BIOPAC SYSTEM MP150 bioelectricity acquisition and processing system. Disposable AgCl electrode placed in the standard position of Del, Tri, Bi and Tra was used for acquiring SEMG. The sampling rate was 1000Hz. After experiment of each scheme, subjective assessment was given by the subjects. The subjective assessment refers to Borg Rating of Perceived Exertion Scale (RPE) [7], which is illustrated in Table. 1.

Table 1. Borg Rating of Perceived Exertion Scale(RPE)

Number	Level of Fatigue
6	No exertion at all
7	Extremely light
8	
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard (heavy)
16	
17	Very hard
18	
19	Extremely hard
20	Maximal exertion

3.2 Model Verification Results

The average muscle force of Del, Tri, Bi and Tra, and the sum of the four muscles' forces were obtained after processing the 6 earth's schemes' results, which were shown in Figure 1 and Chart 2 separately.

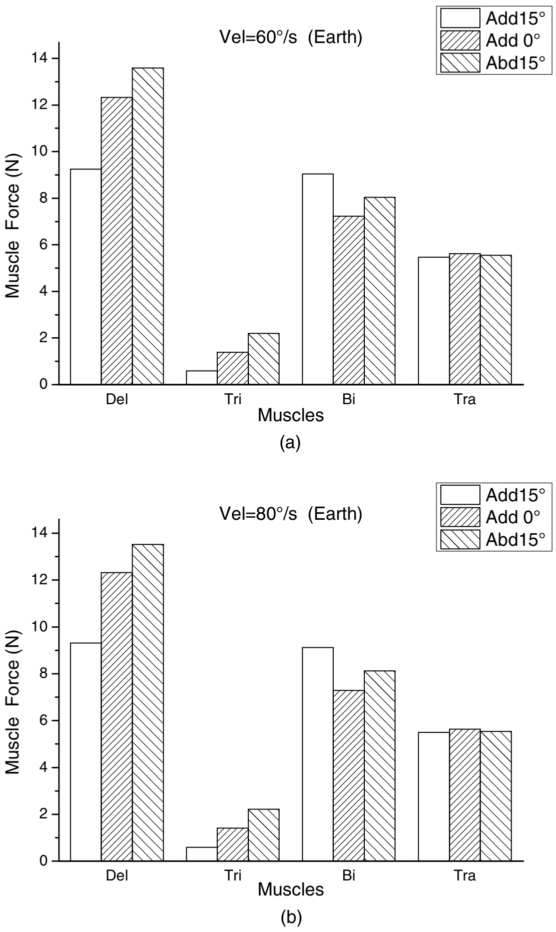

Fig. 1. The average muscle force of four muscles of the earthly simulation (a. Vel=60°/s; b. Vel=80°/s)

Table 2. Earthly simulation results of muscle force sum (N)

	Add 15°	Add 0°	Abd 15°
Vel=60°/s	24.347	26.565	29.384
Vel=80°/s	24.511	26.663	29.390

Figure 1 displays that the average muscle force of the Del and the Tri at the posture of Abb 15°are less than that at Abb 0 °and Abd 15°,which are on the increase along with the shoulder joint's states changing from adduction to abduction. The value of the Tra at the three positions are similar. While the value of the Bi get the minimum at Add 0°, and the value at Add 15°is slightly higher than that at Abd 15°. Accordingly, we can choose the specific scheme as the optimal one based on the specific requirement of a certain muscle. For example, if the Biceps brachii is asked to have the least effort, while no requirements are asserted on other three muscles, the scheme, knocking at Add 0°is the best choice. While considerating the four muscles to give a whole consideration, kocking at Add 15° is the optimum, as three muscles (Tri, Del, Tra) of four are minimal at the position. The sum of the four muscles shown in Chart.2 also supports the view point.

In addition, while knocking move was operated at different angular velocities at the same position,the average muscle force differences are subtle, shown in Chart.2. The value of sum totals of four muscles at the Vel of 80°/s is slightly greater than that at the Vel of 60°/s. While the influence of the knocking velocity is very slight, and it won't influence the distribution of average muscle force at the three positions.

To sum up, among the 6 schemes simulated under the earth's environment, the scheme of knocking at the velocity of 60°/s and at the position of Add 15°is the optimal one.

In the verification experiment, SEMG data were filtered by the 20~500Hz band pass filter and 50Hz band stop filter. To analyse the data, five obvious and consecutive waves were cut out from the whole EMG.

In this study, absolute waveform average was the analysis index. The absolute waveform average is the average of instantaneous EMG amplitude in a period of time, which can display the number, the types and the synchronization of active motion units when muscles acted, and which is also related to the central neural control function in different muscles under different loads. Considering the individual difference, absolute waveform average was normalized in the paper.(See Fig. 2.)

From Add15°, Add0° to Abd15°, as shown in Fig.2, the normalized data of Del, Bi, Tra increased while the Tri decreased slightly. The advantage of the add15° is obvious for the muscle force in that position is smaller to most muscles. In the matter of velocity, the value at 80°/s is always greater than that at 60°/s, but the trend to position stays the same. That is to say, the velocity has something to do with muscle force, but it doesn't influence the position trend. In conclusion, Add15°, Vel=60°/s is the best in the all six schemes.

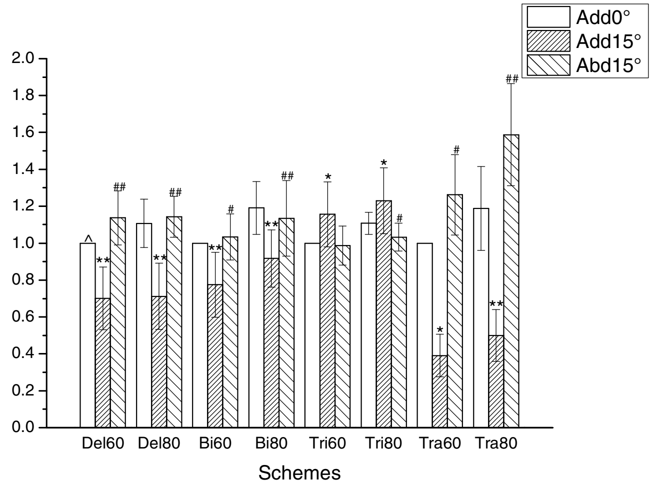

Fig. 2. The normalized results of absolute waveform (* means compared to Add 0°, the difference is significant（p<0.05）;# means compared to Add15°, the difference is significant（p<0.05）;^ means compared to Abd15°, the difference is significant (p<0.05）;##,** means extremely significant difference（p<0.01））

The subjective assessment results are shown in Fig.3.

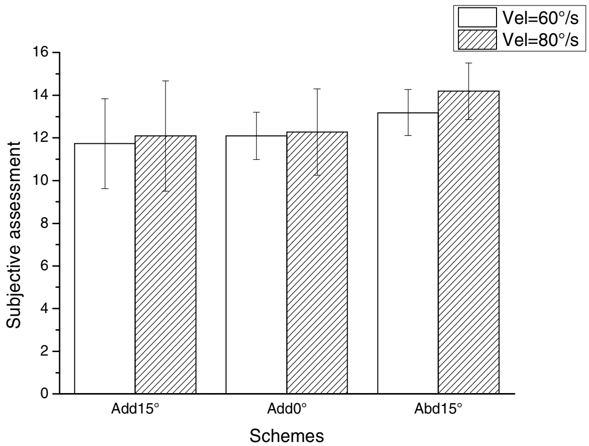

Fig. 3. The subjective assessment results

As in Fig.3, from adduction to abduction, the number of subjective assessment increased one by one, in other words, subjects think it's more and more difficult to knock. Seen from the data at 80°/s and 60°/s, the velocity has impact on subjective scores, while it doesn't affect the whole trend in different positions. Thus, the subjective assessment was well corresponding with the SEMG results. Add15°, Vel=60°/s is also the optimum scheme.

As a whole, the AnyBody software calculation results was coincide with the verification experiment results under the earth gravity. So, it is credible that the optimum scheme for different projects can be calculated through the AnyBody software. This has provided a way for us to study the schemes under the lunar gravity.

4 Selection of Moon Optimal Scheme

After dealing with the 15schemes calculation results under the lunar gravity by AnyBody software, the average muscle force and muscle force sum of Del, Tri, Bi and Tra were got.(See Table 3 and Fig.4).

Fig.4 shows the muscle force trend of different positions under 3 velocities. Considering protecting astronauts' Tri, Add15°is the optimum scheme. If only consider the muscle force of Del, Add0° may be the best.

Fig.5 illustrates the muscle force under different velocity in the position of Add15°. From the Fig.5, under 3 different velocities, the muscle force of Del, Tri, Tra change slightly, but the muscle force of Bi increases along with the velocity.

In order to get the most labor-saving knock scheme and ensure the comfort of most muscles, choosing the sum of 4 muscles (See Table 3)as the index [14], Add15°, Vel=60°/s is the best scheme.

Table 3. Lunar simulation results of muscle force sum (N)

	Add15°	Add10°	Add 5°	Add 0°	Abd 5°
Vel=60°/s	19.372	24.297	27.574	30.496	30.937
Vel=70°/s	21.957	24.343	27.684	30.467	33.218
Vel=80°/s	23.042	24.448	27.679	30.482	33.371

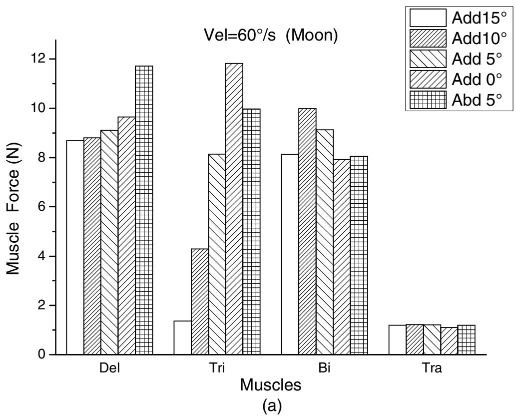

Fig. 4. The average muscle force of four muscles of the lunar simulation (a. Vel=60°/s, b. Vel=70°/s, c. Vel=80°/s)

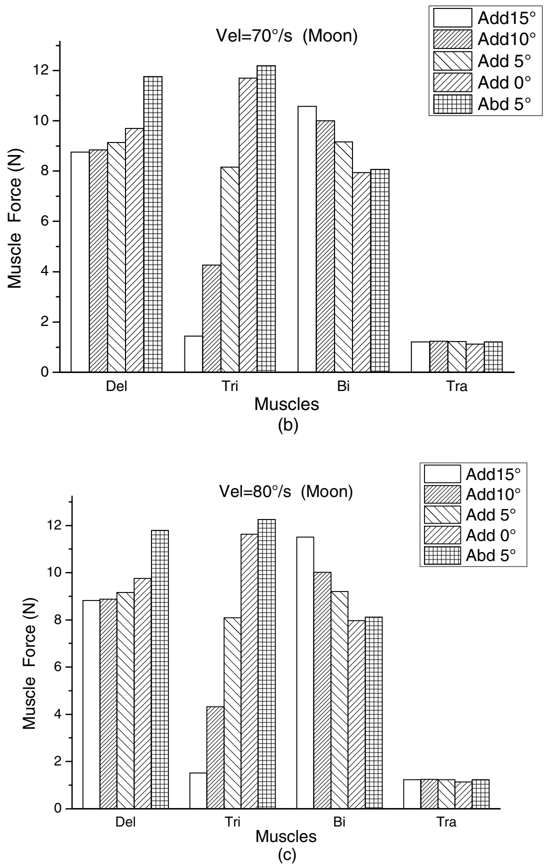

Fig. 4. (*Continued.*)

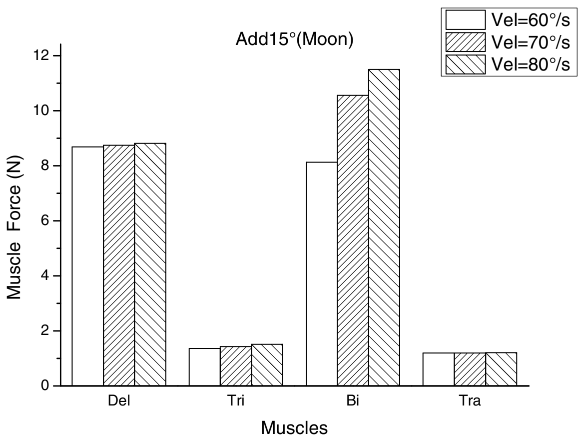

Fig. 5. The average muscle force of muscles under different velocity (Add15°)

5 Conclusion

Through the verification experiment, simulation by using AnyBody software is feasible.

In this paper, we set the knock project as an example, and provide a way to choose better training scheme for future lunar missions as well as other similar missions. This method can improve training efficiency greatly and reduce the workload in optimizing the training scheme.

The training schemes for astronauts are various and complicated especially the lunar mission, which add a lot of new tasks. Therefore, the aware of using simulation to optimize training scheme is indispensable and particularly important. This study laid the foundation of choosing more complex and changeable lunar training scheme for further.

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