ENGELLİLERE YÖNELİK BİR MOBİLİTE DESTEK SİSTEMİ TASARIMI İÇİN DOĞRULMA HAREKETİNİN BİYOMEKANİK ANALİZİ

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ÖZET

Engellilere yönelik bir mobilite destek aracının tasarımı için doğrulma hareketi incelenmiştir. Geliştirilen görüntü yakalama sistemi ve vücuda sabitlenen işaretleyiciler aracılığıyla kinematik veriler kaydedilmiş ve görüntü işleme yöntemleriyle eklem koordinatları elde edilmiştir. Hareketleri tanımlayan kartezyen koordinat bilgisinden yola çıkılarak eklemlere ait açısal konumlar elde edilmiştir. Kinematik veriler statik kuvvet ve güç analizlerinde kullanılmıştır. Bu çalışmadan elde edilen sonuçlar planlanan mobilite destek sisteminin olurluğuna işaret etmektedir ve ön tasarımına yönelik bir temel oluşturmaktadır.

Anahtar Kelimeler: Doğrulma hareketinin biyomekaniği, mobilite destek sistemi, doğrulma hareketi analizi

BIOMECHANICAL ANALYSIS OF SIT-TO-STAND MOTION TOWARDS DESIGN OF A MOBILITY ASSIST DEVICE FOR PEOPLE WITH DISABILITIES

ABSTRACT

A typical sit-to-stand movement analysis is analyzed in designing a mobility assist device for people with disabilities. An in-house motion-capture system was utilized for collecting the kinematic data, in which the motion of markers affixed to a moving subject is recorded, followed by image processing to obtain the coordinates of the markers. These coordinates are then processed to obtain the kinematic variables that describe joint angular movements. Hence, using the kinematic data collection, static force and required power analyses are performed. Results of this study indicate the feasibility of the assist device and form a basis for its design specifications.

Keywords: Biomechanics of sit-to movement, mobility assist device, Sit-to-stand motion analysis.

1. LITERATURE SURVEY

Some of the mobility assist devices and their producers are presented in Figure 1.

Figure 1. Some of the available mobility products

Their common feature is to provide the disabled people with some mobility advantages. Products a and b help the disabled person with sitting and standing, while the products c and d are typical rehabilitation devices used to improve physical capabilities. The device that is being developed will be an alternative to the above devices but provide the patient with more freedom to perform daily household tasks.

2. METHOD

The test group consists of 5 people (aged 22-24 years, weight 67-105 kg, height 174-190 cm). All the test subjects are healthy, without any musculoskeletal system problems. 4 body markers are placed on ankle, knee, hip and shoulder joints. The subjects are told to take a comfortable position at the beginning of each experiment. The speed of the individual’s motion is not altered. The experiment is applied at three different sitting heights (50, 57, 64 cm) for each subject to gain an insight about a typical sit-to-stand movement pattern. Figure 2 shows four captured sequential frames from one of the experiments.

Figure 2- Sequential frames captured

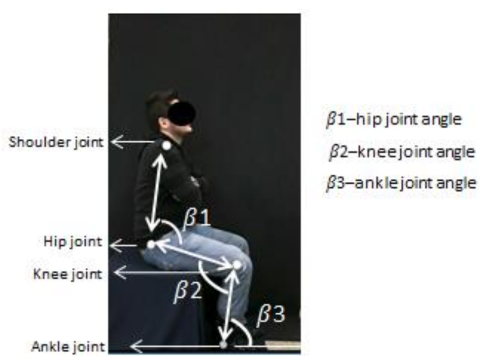

Figure 3. Measured joint parameters in the sagittal plane, [1]

Figure 3 illustrates marker positions and evaluated joint angles. Each marker is located at a position of the relevant joints.

3. RESULTS

3.1 Angular & Linear Motion Analysis

Angular and linear motion analyses are illustrated for one of the subjects whose weight is 76 kg, and height is 174 cm.

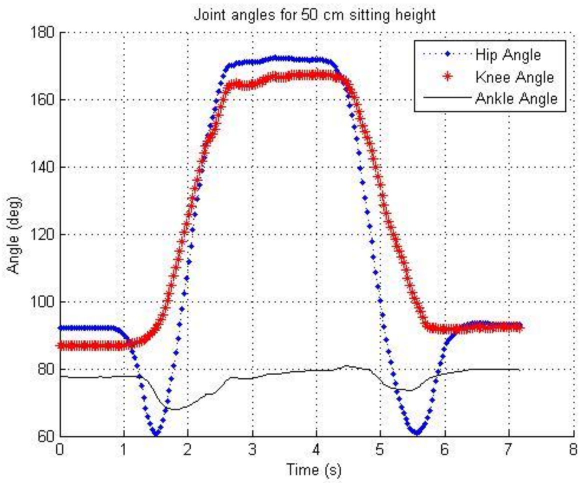

Figure 4. Change of joint angles

Each joint angle is calculated with respect to time as shown in Figure 4. The test subject begins standing up after one second and he stands up at 3.5 seconds. He begins sitting down again and one cycle sit-to-stand cycle is completed in 7 seconds.

Figure 5 illustrates hip and shoulder trajectories of the subject. Hip is considered at zero initial reference in horizontal direction since ankle joint is nearly stationary.

For each test subject, a summary of the angular motion is given in Table 1. All dimensions are in degrees.

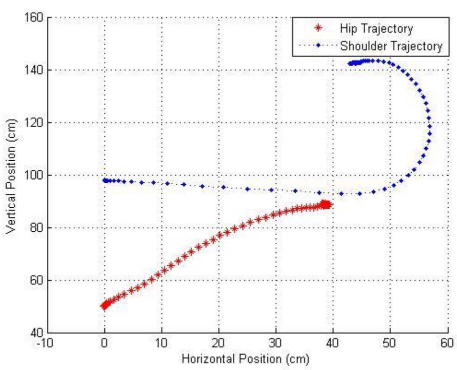

Figure 5. Hip and shoulder trajectories

3.2. Force Analysis

Static force analysis has been done to see how a person could be supported and balanced safely, while he is being lifted up. An external force is applied from three points, chest, hip and knee portions of the body as shown in Figure 6.

Two equilibrium and one moment equations are solved for each body segment using each joint angle found in the previous section. Figure 7 shows calculation of applied and joint reaction forces on chest. F_1 is applied external force on chest, R_{1x} is horizontal reaction force on hip joint, R_{1y} is vertical reaction force on hip joint. Table 2 shows the maximum required forces and calculated reaction forces on each segment and joint of the body.

Table 1. Summary of angular motion for 50 cm sitting height

Position/Subject No		Ankle(°)	Knee(°)	Hip(°)
Standing Configuration	Subject 1	78.60	166.60	172.00
	Subject 2	82.30	170.90	176.00
	Subject 3	84.00	170.00	172.80
	Subject 4	87.00	179.00	172.00
	Subject 5	75.00	168.40	173.00
	Mean	81.38	170.98	173.16
	S.Deviation	4.68	4.77	1.65
Sitting Configuration	Subject 1	77.60	86.70	92.00
	Subject 2	83.40	88.80	98.70
	Subject 3	87.90	97.80	90.06
	Subject 4	82.87	95.00	111.60
	Subject 5	73.48	91.80	106.60
	Mean	81.05	92.02	99.79
	S.Deviation	5.59	4.50	9.25
Range of Angular Motion	Subject 1	1.00	79.90	80.00
	Subject 2	1.10	82.10	77.30
	Subject 3	3.90	72.20	82.74
	Subject 4	4.13	84.00	60.40
	Subject 5	1.52	76.60	66.40
	Mean	2.33	78.96	73.37
	S.Deviation	1.55	4.67	9.54

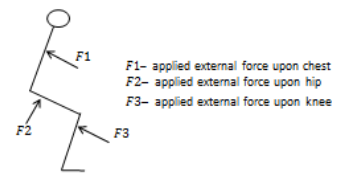

Figure 6. Three applied forces to lift the person

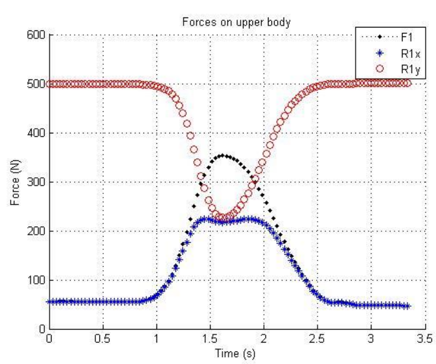

Figure 7. Plot of applied force and joint reactions with respect to time

3.3. Power Analysis

For a selected test subject power has been calculated for one cycle of the sit-to-stand motion by modeling the subject in MATLAB/SimMechanics environment. The duration for one cycle of the motion is 20 seconds.

Table 2. Maximum forces calculated from each segment

Segment	F_i (N)	R_ix (N)	R_iy (N)	$\|R_i(N)\|$ Joint reaction force
İ=1, Chest	353	224	501	548
İ=2, Thigh	556	-153	573	593
İ=3, Shank	281	150	580	599

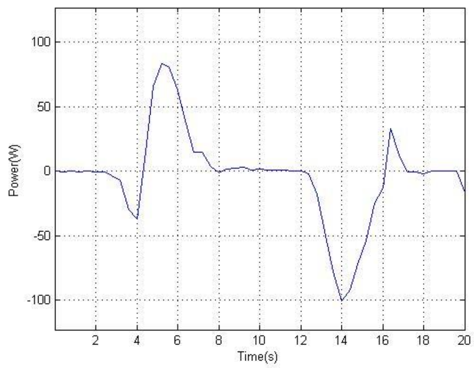

Figure 8. Instantaneous power consumption by the subject

Instantaneous power consumption is computed (Figure 8). Positive values show work done against the gravity and negative values show work done by the gravity. About 80 W positive power is required to bring the subject to standing position, whereas 100 W negative power is required during transition from standing to the sitting position.

4. DISCUSSION

Throughout this study, kinematic data is collected by capturing motions of the subjects. These data yields human sit-to-stand motion trajectory and are used in force and power calculations Results give an insight about the forces that the test subjects and the mobility device are exposed to. Power required to lift and down the impaired is computed by modeling the subject’s movement. Results obtained by the proposed method can be utilized for the design of a novel mobility assist device for disabled people.

REFERENCES

[1] Doğan U, Design of a Mobility Assist Device for Physically Impaired People, Graduation Thesis, Yeditepe University, 2011.
[2] Robertson D.G, Caldwell G.E, Hamill J, Kamen G, Research Methods in Biomechanics, Human Kinetics, 2004.
[3] Winter D.A., Biomechanics and Motor Control of Human Movement, Wiley, 2005.