Sit to Stand Control for Patients with Osteoarthritis and Total Knee Arthroplasty

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ABSTRACT

This study compared the control of sit-to-stand task (STS) in patients with knee osteoarthritis (OA) and patients with total knee arthroplasty (TKA) with normal control (NC). ***Methods:*** *A total of 38 subjects performed single-legged STS task, on affected leg, on a force platform. STS time and center of pressure path length (CPPL) were estimated. Kruskal Wallis test was used to test differences among groups. Results: there was significant difference among groups in STS time and* Fz_{max}*. The follow up tests revealed that OA group had a significantly longer average time and higher* Fz_{max} *values than NC. TKA group was not different from either group in STS time and was significantly different from OA group in* Fz_{max}*.* ***Discussion:*** *The OA group stood up slower and relied on arm support more than NC and TKA groups. The TKA and NC groups were similar in using the arm support. The results revealed that the TKA group was not significantly different from normal in STS time and use of arm support. The STS time measurement is a simple and economic tool that found difference between OA, and NC groups during single-legged STS.*

INTRODUCTION

Osteoarthritis (OA) is the most common arthritic disease in the world and the knee is the most often-affected weight bearing joint (Martin, 1994). Since STS is a prerequisite for upright mobility, inability to perform this task may affect the person's general mobility and may lead to disability and institutionalization (Pai et al., 1994-a). An accurate description of this maneuver may provide useful information for the design and implementation of appropriate therapeutic and rehabilitative interventions needed to ensure an independent life style (Lundin et al., 1995).

The STS movement requires large moments, particularly at the hip and knee joints. Such forces can be reduced when using a relatively higher chair, armrests or an optimal initial foot position (Rodosky et al., 1989; Stevens et al., 1989). STS transfer involves a forward momentum, which allows shifting of the Center of Gravity (CG) in a forward direction, followed by a braking force that limits further travel of the CG outside the Base of Support (BOS). A vertical momentum is then needed to overcome the effect of gravity and complete the STS transfer. While failure to initiate forward or vertical momentum leads to inability to perform STS, failure to control forward and/or vertical moments may cause a loss of balance and falling (Pai et al., 1994-b).

Control of balance is achieved by integrated sensory, motor and neural systems that control the relationship between CG and BOS as well as internal and external forces (Nashner, 1997). Unless sufficient balance control exists to keep the CG within the BOS, loss of balance will occur. The Center of Pressure (CP) during STS represents the total torque applied at the support surface to control the displacement of body mass (Geurts, 1993; Maki et al., 1994). Clendaniel and Durham (1996) reported that during movement, the vertical projection of CG might not coincide with the CP so that additional muscular or inertial forces are required to maintain stability. The relationship between the CP and CG is dependent on the frequency of oscillation. The greater the frequency, the larger the difference between CP and CG excursions and consequently a greater moment is required to control the CG and maintain stability (Murray et al., 1975). The CG oscillation that may be well within the BOS of a healthy individual may be destabilizing to an individual with biomechanical or neuromuscular problems. It is difficult to quantitatively differentiate between normal and abnormal stability, especially during dynamic motion. Murray et al. (1967) reported that during STS, the CP showed a large excursion to produce a smooth and gradual transition of the CG pathway. The CG moved forward while the CP moved initially in front then behind the CG to reduce the work required to execute the movement.

The purpose of the present study was to evaluate STS control in patients with OA and TKA compared to a normal, age matched population.

We hypothesized that there would be differences between groups in the control of STS movement as evidenced by differences in the CPPL and time variables. Because there was variability in the use of armrest support among groups we measured the percentage of body weight transferred to the supporting lower extremity versus that transferred to armrests.

MATERIAL AND METHODS

Subjects:

A total of 38 participants were recruited as a sample of convenience. Approval for the test procedure was obtained from the institutional Review board and all participants read and signed the informed consent prior to the test. Anthropometric data (height, weight and age) were obtained from all participants (table 1). The three groups consisted of: (1) OA group; five males and seven females, who were diagnosed with chronic knee OA; (2) TKA group; seven males and six females, who had TKA surgery related to their OA at least one year before testing and (3) NC group; seven males and six females who were in good health and free from any chronic or acute illness, lower extremity pain, disability or recent injury. Effort was made to match the physical characteristics between all groups (table 1).

Instrumentation:

An AMTI force platform (FP) model OR6-7-2000measured ground reaction force data that was recorded by an Ariel Performance Analysis System (APAS). The analog signals collected from the FP were converted to a digital format by an A/D converter then were exported to an Excel file for an off-line analysis.

Procedure:

Participants were instructed to use the armrests as they stood from an adjustable chair (adjusted to 90° knee flexion for each subject) at a comfortable pace on the tested leg. The OA and TKA groups were asked to perform the STS task using the involved leg only. The NC group was asked to use the matching leg. Participants were asked to perform three repetitions of single-leg STS while avoiding any contact of the untested leg with the floor or chair. The Center of Pressure Path Length (CPPL) was then calculated from moments around X and Y-axes (Mx and My). The CPPL and the time needed to complete STS movement (STS time) were calculated between time to minimum and time to maximum vertical forces ($Fz_{(Tmax–Tmin)}$). The average CPPL and average time over the three trials were calculated for each subject. The contribution of armrests during the movement was calculated from average maximum vertical force on the FP (Fz_{max}) normalized to body weight. The more the participants used the armrest support the less the pressure they applied on the FP and the smaller the Fz_{max} as a percentage pf body weight.

Statistical Analysis

Descriptive statistics, histograms, scatter plots and bivariate correlations were calculated (using SPSS) to screen all data for errors, check normality assumptions and detect outliers. Levene's test was used to examine homogeneity of variances. Data screening revealed that there was violation of homogeneity of variance and some influential, but real scores. Because ANOVA is not robust to violations of homogeneity of variance and unequal sample size, the nonparametric Kruskal-Wallis analysis of variance and the follow up multiple comparisons were used. ANOVA was used to test if the physical characteristics of the groups were different.

RESULTS

The results of this study showed that matching of the physical characteristics was adequate. The group means and standard deviations for age, height and weight for subjects in the OA, TKA and NC groups are presented in Table 1. The age, height and weight were not significantly different among groups (age: $F_{2,35}$= 1.01, p= .37; height: $F_{2,35}$=

1.05, P= .36; and weight: $F_{2,35}$= 0.57, P= .57). Data screening showed two scores in the OA group that would be considered as influential points on scatter plots and test of influential points. Decision was made to keep these scores because they reflected real performance and represented the variability of patient population. Levene's test also revealed that the variances of STS time, Fz_{max} and CPPL were significantly heterogeneous at P= .026, P < .001) and P= .014 respectively. Descriptive statistics and mean ranks for the CPPL, Fz_{max} and the STS time variables are presented in Table 2. The Kruskal-Wallis test demonstrated a non-significant difference between groups in the CPPL but a significant difference between groups in the STS time and Fz_{max} variables. The Kruskal-Wallis follow-up multiple comparison tests at alpha = .05 revealed that the STS time was significantly different between the OA and NC groups. The STS time was not significantly different between the TKA group and both OA and NC groups. The mean ranks for STS time were 25.17, 20.12 and 13.65 for OA, TKA and NC groups respectively. Also the TKA and NC groups had significantly greater Fz_{max} than the OA group with mean ranks of 25.9, 23.2 and 8.6 respectively. The normalized means of Fz_{max} were 106%, 105% and 95% of body weight for maximum vertical force for TKA, NC and OA groups, respectively. Fz_{max} was not significantly different between TKA and NC groups.

Table (1): Means and standard deviations for the physical characteristics of the osteoarthritis (OA), total knee arthroplasty (TKA) and normal control (NC) groups.

	OA (± St.Dev.)	TKA (± St.Dev.)	NC (± St.Dev.)
Age (yrs)	64.83 (8.73)	68.92 (7.15)	68.38 (7.38)
Height (inches)	64.98 (2.46)	67.13 (5.08)	65.76 (3.20)
Weight (lb)	178.42 (3.81)	193.19 (36.52)	180.69 (39.13)

Table (2): Means, standard deviations and mean ranks for the Center Of Pressure Path Length (CPPL), STS time and Maximum Vertical Force Fzmax variables of the osteoarthritis (OA), total knee arthroplasty (TKA) and normal control (NC) groups.

Mean (± St.Dev.)	OA (± St.Dev.)	TKA (± St.Dev.)	NC (± St.Dev.)
Mean CPPL (cm)	23.10 (14.99)	17.52 (4.78)	16.16 (4.58)
Mean Rank	21.83	19.38	17.46
Mean STS time (Sec)	1.72 (0.74)	1.36 (0.42)	1.12 (0.32)
Mean Rank	25.17	20.12	13.65
Fz_{max}	95.45 (10.46)	106.12 (2.85)	105.26 (2.45)
Mean Rank	8.58	25.88	23.19

Table (3): Median test results by rank for the Center of Pressure Path Length (CPPL), STS time and Maximum Vertical Force Fzmax variables for the osteoarthritis (OA), total knee arthroplasty (TKA) and normal control (NC) groups.

	OA	TKA	NC
CPPL			
> median	66	6	7
≤ median		7	6
Fz max %body			
weight > median	1	10	8
≤ median	11	3	5
STS time			
> median	9	5	5
≤ median	3	8	8

DISCUSSION

The results of this study confirmed the difference in physical performance for the group with the intervention of TKA as reported by other studies (Skinner, 1993; Kirwan et al., 1994; Andriacchi et al., 1982; Rolauffs et al., 2005). This study revealed a significant increase in weight bearing (less need to use arm support) and decrease in the time needed for the STS movement. The results of this study revealed that the OA group needed longer time than the NC group to complete the STS task. The lack of significant difference between the OA and TKA and between the TKA and NC groups may suggest a state of recovery from osteoarthritis following the intervention of TKA.

The significantly longer time and reliance on armrest support by the OA group as compared with the NC group found in this study might reflect one of the compensatory mechanisms that takes place to substitute for poor balance control. The OA subjects might have increased the STS time and increased the use of the armrests than NC group as a compensatory strategy to achieve the STS task with limited CP excursion that was not different from normal (Table 2). Clinically, the measurement of time is an easy and economic way to test and document functional status. Howe et al. (1995) also defined the timed STS test as a reliable and consistent measure of functional ability in osteoarthritic subjects. There was no CPPL difference between groups supporting other studies, which have shown the changes, which might affect the stability, are tightly regulated and compensated through learning of a new motor strategy (Pai et al., 1994). Table 3 shows that all three groups had very similar CPPL above and below median. Pai and Rogers (1990) reported that changing the speed of chair rise only affected the time to maximum vertical momentum while the time to the maximum horizontal momentum was unchanged. They also found that the greater forward momentum was opposed by a greater braking impulse used to control the movement in the anteroposterior direction. Pai et al. (1994) reported no difference between young and elderly groups in the horizontal displacement of the CG during STS. They suggested that the horizontal displacement of CG reflected a strategy related to the control of balance. Magnan et al. (1996) reported that during STS the forward momentum increased only when the subjects were asked to initiate walking after the STS task. Schultz et al. (1992) reported that during chair rise the elderly population used the armrests more to achieve stability than to reduce the knee joint torque requirement.

No previous studies reported the comparisons between OA, TKA and NC groups. However, a few studies have reported the increase of CP displacement measures with age and with increased risk of falling (Maki et al., 1994; Thapa et al., 1994; Murray et al., 1967). Comparing young and elderly normal individuals, Murray et al. (1975) reported the young group had larger limits of stability and a smaller CP excursion than the elderly group. They summarized that the elderly group was either at greater risk of fall or required greater effort to control the CP excursion.

Limitations of the study: The severity of OA was not controlled for and may have influenced the outcomes of the study.

Suggestion for further studies: study the changes in the control of STS during step initiation following the STS movement, which is the functional purpose of STS. Include osteoarthritic patients that have only stage 2 and 3 to reduce variability in this population.

Conclusions:

Because balance control during STS is important, the OA subjects may have increased the STS time and the use of armrests to control CP displacement. After the intervention of TKA surgery patients may have reduced reliance on armrests and reduced the time to achieve STS to be similar to the NC group.

REFERENCES

1- Clendaniel, R. and Durham, N.C.: Critical analysis of measurement of balance: A technological perspective; in Preceding of the 16th Annual Eugene Michels Researchers' Forum. Section on Research. APTA Combined Sections Meeting. Atlanta, Georgia, 1996.
2- Gill, T.M., Williams, C.S. and Tinetti, M.E.: Assessing risk for the onset of functional dependence among older adults: The roll of physical performance. JAGS, 43(6):603-609, 1995.
3- Howe, T. and Oldham, J.: Functional tests in elderly osteoarthritic subjects: Variability of performance. Nurs Stand., 9(29):35-39, 1995.
4- Kirwan, J.R., Currey, H.L.F., Freeman, M.A.R., Snow, S. and Young, P.J.: Overall long-term impact of total hip and knee joint replacement surgery on patients with osteoarthritis and rheumatoid arthritis. Brit J Rheum., 33: 357-360, 1994.
5- Magnan, A., McFadyen, B.J. and St-Vincent, G.: Modification of the sit-to-stand task with the addition of gait initiation. Gait & Posture, 4:232-241, 1996.
6- Maki, B.E., Holliday, P.J. and Topper, A.K.: A prospective study of postural balance and risk of falling in an ambulatory and independent

elderly population. J Gerontol Med Sci., 49(2): m72-m84, 1995.

7- Martin, D.F.: Pathomechanics of osteoarthritis. Med. Sci. Sports Exerc., 26(12): 1429-1434, 1996.

8- Murray, M.P., Seireg, A. and Scholz, R.C.: Center of gravity, center of pressure, and supportive forces during human activities. J Appl Physiol., 23(6): 831-838, 1967.

9- Murray, M.P., Seireg, A.A. and Sepic, S.B.: Normal posture stability and steadiness: Quantitative assessment. J Bone Joint Surg., 57-A: 510-516, 1975.

10- Nashner, L.M.: Practical biomechanics and physiology of balance; In: Handbook of Balance Function Testing; Edited by Jacobson GB., Newman CW. And Kartush JM. Mosby Year Book, St. Louis, 261-279, 1997.

11- Nashner, L.M.: Computerized dynamic posturography; in: Handbook of Balance Function Testing; Edited by Jacobson, G.B., Newman, C.W. and Kartush, J.M. Mosby Year Book, St. Louis. 280-307, 1997.

12- Pai, Y.C.-a, Chang, H.J., Chang, R.W., Sinacore, J.M. and Lewis, J.L.: Alteration in multijoint dynamics in patients with bilateral knee osteoarthritis. Arth. & rheum. 9(9): 1297-1304, 1994.

13- Pai, Y.C.-b, Naughton, B.J., Chang, R.W. and Rogers, M.W.: Control of body center of mass momentum during sit-to-stand among young and elderly adults. Gait & Posture. 2(6): 109-116, 1994.

14- Pai, Y.C. and Rogers, M.W.: Control of body mass transfer as a function of speed of ascent in sit-to-stand. Med. Sci. Sport. Exerc.; 22(3): 378-384, 1990.

15- Rodosky, M.W., Andriacci, T.P. and Anderson, G.B.J.: The influence of chair height on lower limb mechanics during rising. J Ortho Res.; 7(2):266-271, 1989.

16- Rolauffs, B., Plaumann, T., Tibesku, C.O., Rosenbaum, D. and Fuchs, S.: Clinical and functional results after the rehabilitation period in minimally-invasive unicondylar knee arthroplasty patients. Knee Surgery, Sports Traumatology, Arthroscopy; 13(3): 179-186, 2005.

17- Schultz, A.B., Alexander, N.B. and Ashton-Miller, J.A.: Biomechanical analysis of rising from a chair. J Biomech.; 25(12):1383-1391, 1992.

18- Skinner, H.B.: Pathokinesiology and Total Joint Arthroplasty. Clin Ortho Relat Res.; 288(3): 78-86, 1993.

19- Stevens, C., Bojsen-Moller, F. and Soames, R.W.: The influence of initial posture on the sit-to-stand movement. Eur J Appl Physiol.; 58: 687-692, 1989.

20- Tew, M., Froster, W. and Wallace, W.A.: Effect of total knee arthroplasty on maximal. flexion. Clin Ortho Relat Res.; 247(10):168-174, 1989.

21- Thapa, P.B., Gideon, P., Fought, R.L., Kormicki, M., Ray, W.A. Comparison of clinical and biomechanical measures of balance and mobility in elderly nursing home residents. J. Am Ger Soc.; 42: 493-500, 1994.

الملخص العربي

التحكم في الوقوف من الجلوس لمرضى خشونة الركبة والتغيير الكلى لمفصل الركبة

لقد قارنت هذه الدراسة بين التحكم في الوقوف من الجلوس لدى مرضى خشونة الركبة ومرضى الاستبدال الكلى لمفصل الركبة ومجموعة حاكمة من الأشخاص الأصحاء . تكونت عينه البحث من 38 شخصاً قاموا بأداء مهمة الوقوف من الجلوس على الطرف السفلى المصاب فوق قرص حساب القوى التحتية للقدم . تم تقييم الوقت المستهلك لأداء هذه المهمة بالإضافة إلى طول مسار مركز الضغط . تم استخدام اختبار كروسكال واليز لاختبار الفروقات بين المجموعات . أثبتت النتائج وجود فروقات ذات دلالة إحصائية بين المجموعات في الوقت المستهلك لأداء مهمة الوقوف من الجلوس وكذلك في القوى الرأسية . أثبتت اختبارات المتابعة أن مجموعة مرضى خشونة الركبة قد استهلكت وقتاً أطول لأداء المهمة وكانت لهم قيم أعلى في القوى الرأسية أكثر من المجموعة الحاكمة . أما بالنسبة لمجموعة مرضى الاستبدال الكلى لمفصل الركبة فلم تكن هناك فروقات ذات دلالة إحصائية في الوقت المستهلك لأداء الوقوف من الجلوس بينهم وبين الأشخاص في المجموعتين الأخريين ، ولكن كانت هناك اختلافات ذات دلالة إحصائية كمية بين هذه المجموعة وبين مجموعة خشونة مفصل الركبة بالنسبة للقوى الرأسية . أن مجموعة مرضى خشونة مفصل الركبة تقوم بأداء الوقوف من الجلوس أبطأ من المجموعتين الاخريتين وتعتمد أكثر على دعم الذراع . بينما لم تختلف مجموعة مرضى الاستبدال الكلى لمفصل الركبة عن المجموعة الحاكمة فى الوقت المستهلك لاداء الوقوف من الجلوس وكذلك الاعتماد على دعم الذراع . يعتبر قياس الوقت المستهلك للوقوف من الجلوس وسيلة بسيطة واقتصادية اثبتت وجود فرق بين مجموعة خشونة مفصل الركبة والمجموعة الحاكمة اثناء الوقوف والجلوس على قدم واحد .