การทดสอบความแข็งแรงและความทนทานของกล้ามเนื้อขาในผู้ใหญ่ตอนต้นเพศชาย โดยการลุกขึ้นยืนจากนั่งด้วยขาข้างเดียว: การศึกษาในเบื้องต้น

A One-Leg Sit-to-Stand Test for the Measurement of Leg Muscle Strength and Endurance in Young Adult Males: Pilot study

เอกราช วงศ์ษายะ[1] และสมรรถชัย จำนงกิจ[1]

Eakarach Wongsaya[1] and Samatchai Chamnongkich[1]

บทคัดย่อ

การลุกขึ้นยืนจากนั่งด้วยขาข้างเดียว (One-leg Sit-to-stand; STS) เป็นการทดสอบแบบใหม่ที่มีจุดมุ่งหมายเพื่อใช้ประเมินความแข็งแรงและความทนทานของกล้ามเนื้อขาแยกแต่ละข้างได้ วัตถุประสงค์ของการศึกษา เพื่อศึกษาการทดสอบ One-leg STS ในการประเมินหาค่าความแข็งแรงและความทนทานของกล้ามเนื้อเหยียดข้อเข่า โดยการหาค่าความสัมพันธ์ระหว่างตัวแปรที่ได้จากการทดสอบ One-leg STS ชนิดลุกขึ้นยืนแล้วลงนั่ง 5 และ 10 รอบ ได้แก่ เวลาที่ใช้ในการทดสอบ (Time) และค่ากำลังของการลุกจากนั่งขึ้นยืน (Power) กับตัวแปรที่แสดงถึงความแข็งแรงและความทนทานของกล้ามเนื้อเหยียดข้อเข่า ได้แก่แรงหดตัวสูงสุดของกล้ามเนื้อ (MVC) และค่าช่วงเวลาที่ทำให้กล้ามเนื้อล้า (Time to fatigue) ตามลำดับ โดยผู้เข้าร่วมการทดสอบเป็นผู้ใหญ่ตอนต้นเพศชายจำนวน 25 คน อายุเฉลี่ย 21.2 ± 1.6 ปี, น้ำหนักตัวเฉลี่ย 58.1 ± 11.2 กิโลกรัม และส่วนสูงเฉลี่ย 165.3 ± 8.0 เซนติเมตร ใช้การทดสอบ One-leg STS เพื่อวัดเวลาและคำนวณหา Power ใช้อุปกรณ์ PowerLab และ Load cell เพื่อวัดตัวแปร MVC และ Time to fatigue ใช้สถิติ Pearson product moment correlation เพื่อหาค่าสัมประสิทธ์สหสัมพันธ์ระหว่างตัวแปร ผลการศึกษาพบว่า MVC, Time to fatigue, T5-STS, T10-STS, P5-STS และ P10-STS มีค่าเฉลี่ย 253.38 ± 84.81 นิวตัน, 85.92 ± 52.39 วินาที, 6.60 ± 0.66 วินาที, 12.91 ± 1.28 วินาที, 186.32 ± 37.38 วัตต์และ 190.14 ± 34.87 วัตต์ ตามลำดับ มีเพียงความสัมพันธ์ระหว่าง MVC และ Power ที่มีค่าความสัมพันธ์เชิงบวกในระดับสูงอย่างมีนัยสำคัญทางสถิติ ($R \geq 0.7$, $p < 0.01$) จากผลการศึกษาครั้งนี้บ่งชี้ว่าค่าดัชนีกำลังที่คำนวณได้จากการทดสอบ One-leg STS สามารถนำไปทดสอบเพื่อประเมินค่าความแข็งแรงของกล้ามเนื้อเหยียดข้อเข่าในวัยผู้ใหญ่ตอนต้นเพศชายได้ อย่างไรก็ตามการทดสอบ One-leg STS ไม่สามารถใช้วัดความทนทานของกล้ามเนื้อเหยียดข้อเข่าได้

ABSTRACT

A one-leg sit-to-stand test (STS) was a modified test aimed to assess the knee extensor muscle strength and endurance for each leg. The purpose of this study was to explore the use of a one-leg STS test for measurement of strength and endurance of the knee extensor muscles by exploring the relationship between variables obtained from the 5 and 10 repeated one-leg STS tests (time and power of the test) and variables representing strength and endurance of the knee extensor muscles (maximum

[1] ภาควิชากายภาพบำบัด คณะเทคนิคการแพทย์ มหาวิทยาลัยเชียงใหม่ เชียงใหม่ 50200

[1] Department of Physical Therapy, Faculty of Associated medical sciences, Chiang Mai University, Chiang Mai 50200

voluntary contraction; MVC and time to fatigue, respectively). There were 25 young males (mean age 21.2 ± 1.6 year, mean body weight 58.1 ± 11.2 kg and mean height 165.3 ± 8.0 cm) participating in the study. One-leg STS test was used to measure time (Time STS). A PowerLab data acquisition system with load cell was used to measure MVC and time to fatigue of knee extensor muscles. Pearson product moment correlation coefficient statistics was used to determine the relationship between variables obtained from the one-leg STS test and variables representing knee extensor strength and endurance. The results showed that mean MVC, time to fatigue, T5-STS, T10-STS, P5-STS and P10-STS were 253.38 ± 84.81 N, 85.92 ± 52.39 sec, 6.60 ± 0.66 sec, 12.91 ± 1.28 sec, 186.32 ± 37.38 W and 190.14 ± 34.87 W, respectively. There were significant positive correlations between MVC and power of one-leg STS ($R \geq 0.7$, $p < 0.01$). Therefore, the power of one-leg STS test was only one variable which had high correlation to the knee extensor muscle strength. On the other hand, both of time and power variables of one-leg STS test were inappropriate to assess knee extensor muscle endurance. These functional tests; 5 and 10 repeated one-leg STS tests may be used as indicator for measuring the knee extensor muscle strength in young adult males.

Key Words : one-leg sit-to-stand test, knee strength, knee endurance, correlation

E-mail : eaklera@hotmail.com

INTRODUCTION

A sit-to-stand (STS) movement is prerequisite to functional independence. The STS movement uses major force from hip and knee extensor muscles relatively more than other muscle groups (Schultz *et al.*,1992). Wretenberg *et al.* (1994) reported that the knee extensor and hip extensor muscles contribute 72 % and 27 % respectively in STS movement. Several methods are available for measurement of muscle strength: both direct and indirect methods. However, these direct methods have some limitations in clinical use due to high cost and limit availability to only specific hospitals and research laboratories. Thus, direct methods are less applicable than indirect methods (functional tests) for measuring muscles strength for individuals living in community.

In the literature, a STS test has been assessed in association with force-generating capacity of the leg muscle (Corrigan, 2001). Several studies explored the relationship between leg muscles strength and variables derived from the STS test. However, the association between STS performance and leg strength is still inconclusive. Macfarlane *et al.* (2006) found a low correlation between the number of completed standing in a 30 second STS test and maximum isometric voluntary contraction force of the knee extensor muscle in elderly people (r = 0.3 - 0.4). In addition, McCarthy *et al.* (2004) reported that knee extensor and hip extensor muscle's isokinetic peak torque had low to moderate correlation with both of the time to complete a 5 repeated STS test (r = -0.46 for knee extensor and

-0.29 for hip extensor) and the number of completed standing in a 30 second STS test (r = 0.44 for knee extensor and 0.33 for hip extensor). These previous studies suggest that variables directly measured from the STS test such as time and the number of movement were not consistently associated with knee extensor and hip extensor muscle strength.

More recently, Takai *et al.* (2009) studied the relationship between cross-sectional area, maximum isometric voluntary contraction force of knee extensor muscle and the time to complete a 10 repeated STS test. The results confirmed that there was no relationship between time to complete a 10 repeated STS test and each of cross-sectional area and maximum isometric voluntary contraction force. However the power index calculated by time to complete a 10 repeated STS test, body mass and estimated center of mass (CoM) displacement was highly correlated with cross-sectional area (r = 0.80) and the maximum isometric voluntary contraction force (r = 0.73).

Despite these findings, the relationship between muscle endurance and the STS test has been received less attention although muscles endurance might also affect the STS performance. Netz *et al*. (2004) reported no correlation between time to complete a 10 repeated STS test and the knee extensor muscle isokinetic endurance.

Most of previous studies related to the STS test were done in elderly population. The STS test was performed with two leg support that is a safety protocol for elders who might have balance deficit (Bohannon, 1998). However, the STS test may be appropriate for testing in young adult if the protocol is modified to be more physically challenging. Standing up and sitting down using one leg requires higher amount of force generated from knee extensor muscle to control the movement of the whole body. In addition, one-leg STS test can be used to isolate strength measurement for each leg. Therefore, it is of interest to validate if the one-leg STS test can be used to assess knee extensor muscle strength and endurance in young adults. Only male will be assessed in this study to eliminate gender effect to muscles strength and endurance.

The main purpose of the study was to explore the use of a repeated one-leg STS test for assessment of strength and endurance of the knee extensor muscle by exploring the relationship between variables obtained from the 5 and 10 repeated one-leg STS tests (time to complete the 5 and 10 repeated one-leg STS tests and power of the test) and variables representing strength and endurance of the knee extensor muscles.

METHODS

25 male (18 to 25 years old without neurological and musculoskeletal disease) voluntarily participated in the study. There were two testing sessions for data collection. The first session was set up for the 5 repeated and 10 repeated one-leg STS tests. Each participant sat on a chair with arms

across his or her chest. Seat height was set to 120% of participant lower leg length. The tested (dominant) knee was set at 100° of knee flexion. The untested (non-dominant leg) was held in same position but the foot was not in contact with the floor. Participants were encouraged to perform the 5 and 10 repeated one-leg STS with maximum effort as fast and safe as possible. The time (T-STS) was recorded using a stopwatch. The test was started when the tester said "Go" and ended when the participants fully sat on the 5^{th} or 10^{th} repetition, for the 5 and 10 repeated one-leg STS tests, respectively. Participants were tested twice for each of the 5 and 10 repeated one-leg STS tests. The trial with the best (shortest) time from the two trials was selected for data analysis. The power of one-leg STS movement is calculated by time to complete a STS test, body mass and estimated center of mass (CoM) displacement as previously described by Takai *et al.* (2009). Difference in body height between sitting and standing was used to estimate body CoM displacement.

$$\text{Power STS} = \frac{\text{Body CoM displacement} \times \text{Body weight} \times \text{Number of repetition of STS test}}{\text{Time STS}}$$

In the second session, knee extensor strength and endurance were tested. Maximum isometric contraction of the knee extensor muscle strength (MVC) was measured using a strain-gauge load cell connected to a PowerLab data acquisition system. Each participant sat on a chair with the knee angle at 60° flexion. The load cell was placed at anterior aspect of the shank one inch proximal to the lateral malleolus. During the test, each participant performed 3 maximal effort of knee extension isometric contraction with a 2 minutes rest between efforts. The trial with highest value of the three contractions was recorded as the MVC (Allaire *et al.*, 2004).

Following a 15 min rest, a knee extensor muscle endurance test was performed. The same starting position as the knee extensor muscle strength test was set. Participants were instructed to contract the knee extensor muscle against the load cell and maintain the contraction force equal to 60% of their MVC as long as possible until the force level reduced to 50% MVC. Muscle endurance was assessed by the time to fatigue, defined as the period of time between an instant when force reaching 60% MVC and an instant when force reducing to 50% MVC (Allaire *et al.*, 2004).

Pearson product moment correlation coefficient statistics was used to determine the relationship between variables obtained from the one-leg STS test and variables representing knee extensor strength and endurance. The alpha level was set at $p<0.05$ for all statistical tests.

RESULTS AND DISCUSSION

1. Knee extensor muscle strength and endurance

The mean values of knee extensor muscle isometric MVC and knee extensor muscle time to fatigue were 253.38 $\pm$ 84.81 N and 85.92 $\pm$ 52.39 sec, respectively.

2. Time and power of one leg sit-to-stand tests

In present study, the mean time to complete 5 and 10 repeated one-leg STS tests were 6.60 and 12.91sec, respectively (Table 1). Therefore, the mean time per 1 repetition were 1.32 and 1.30 sec, respectively. In the study by Takai *et al.* (2009) the mean time to complete 10 repeated two-leg STS tests was 10.3 sec (The mean time per 1 repetition was 1.03 sec). In the present study, mean power of 5 and 10 repeated one-leg STS test (P5-STS and P10-STS) were 186.32 and 190.14 W, respectively (Table 1). Takai *et al.* (2009) reported slightly greater mean P10-STS of 184 W.

Although participants in this present study had relatively larger body structure (body weight and height) compared to participants in Takai's study (2009) and performed a STS movement with one leg which is more difficult compared to two-leg STS movement, the difference in time and power of the STS test between two studies was quite small. The reason might be that young population of this present study was able to use one-leg to control the movement effectively than elderly population due to relatively greater muscle strength in young adults.

Table 1 Time to complete and power of one-leg sit-to-stand tests

Type of one leg sit-to-stand test	Time to complete (sec)	Power (W)
5 repeated one-leg STS	6.60 ± 0.66	186.32 ± 37.38
10 repeated one-leg STS	12.91 ± 1.28	190.14 ± 34.87

Note: Data are mean ±SD.

3. Relationships between the one-leg STS test and knee extensor muscle strength and endurance

There was no correlation between MVC and time variables (T5-STS and T10-STS) in this present study. Ferrucci *et al.* (1997) reported that the relationship between time to complete 5 repeated two-leg STS test and knee extensor muscle force was not linear if the participant had MVC greater than 98 N. All of participants in present study had knee extensor muscle MVC above 98 N (mean = 253.38 N, range = 127.33 – 491.12). Therefore, it can be assumed that the relationship between time variable and MVC in the present study was in the plateau part of the relationship between time and MVC. This suggested that a measure of time to complete one-leg STS test was not consistently related with knee extensor muscle strength. Individual differences in physical characteristics such as body weight and leg length also lead to differences in the distance of the center of gravity during movement, and in turns affect the mechanical work and power during the sit-to-stand task.

In present study, a positive relationship between power of a one-leg STS (P5-STS and P10-STS) and MVC was found which confirmed our research hypothesis. This finding was in agreement with the study of Takai *et al.* (2009). Although in this present study one-leg STS test was performed, the relationship between power STS and MVC still high (r = 0.77 and 0.70, respectively). This suggests that participants with high knee extensor muscle strength will have high value of STS power. From results as shown in Figure 1, participants with low MVC also had low power output and participants with high MVC values also had high power output.

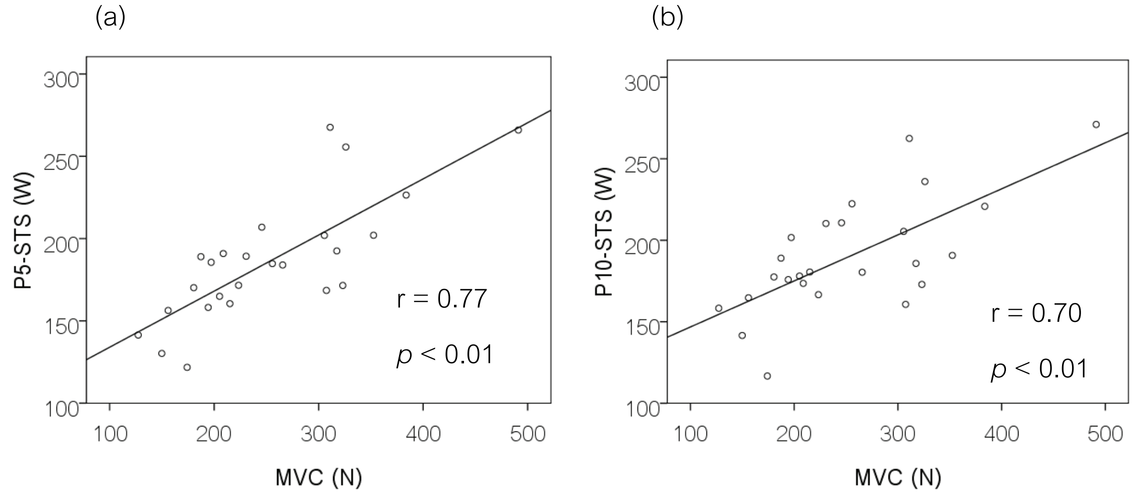

Figure 1 Relationship between knee extensor muscle MVC and power of the 5 repeated (a) and 10 repeated (b) one-leg STS tests

There were no correlation between time to fatigue and variables obtained from the 5 and 10 repeated one-leg STS tests, similar to the study by Netz *et al.* (2004). This present study used the isometric endurance test as described by Allaire *et al.* (2004). The mean time to fatigue of this present study was 85.92 sec but time to complete one-leg STS (T5-STS and T10-STS) were 6.60 and 12.91sec, respectively. It is possible that, the one-leg STS tests used in this study were not strenuous enough to induce knee extensor muscle fatigue therefore, a strong relationship between time to fatigue and variables of the one-leg STS can not be found. In the study by Kawabata *et al.* (2000), knee extensor and flexor muscle endurance were assessed using isokinetic dynamometer. The participants performed 50 repetitive maximal concentric contractions to determine the fatigue rate but in this present study the one-leg STS tests performed only 5 and 10 repetition. The insufficient in repetitive work in the one-leg STS tests might not sufficiently induced knee extensor muscles to its endurance state.

However, the participants in this study were relatively small. Further studies should investigate to ensure the results of this present study in a large sample size.

CONCLUSION

This study showed that the power of one-leg STS test was only one variable which had high correlation to the knee extensor muscle strength. On the other hand, both of time and power variables of one-leg STS test were inappropriate to assess knee extensor muscle endurance. These functional tests; 5 and 10 repeated one-leg STS tests may be used as indicator for measuring the knee extensor muscle strength in young adult males.

REFERENCES

Allaire, J., F. Maltais, J.F. Doyon, M. Noel, P. LeBlanc, G. Carrier and *et al.* 2004. Peripheral muscle endurance and the oxidative profile of the quadriceps in patients with COPD. **Thorax** 59: 673-678.

Bohannon, R.W. 1998. Alternatives for measuring knee extension strength of the elderly at home. **Clin Rehabil** 12: 434-440.

Corrigan, D., R.W. Bohannon. 2001. Relationship between knee extension force and stand-up performance in community-dwelling elderly women. **Arch Phys Med Rehabil** 82: 1666-1672.

Ferrucci, L., J.M. Guralnik, D.M. Buchner and *et al.* 1997. Departures from linearity in the relationship between measures of muscular strength and physical performance of the lower extremities, the woman's health and aging Study. **J Gerontol A Biol Sci Med** 52: M275-M285

Kawabata, Y., M. Senda, T. Oka, Y. Yagata, Y. Takahara, H. Nagashima and *et al.* 2000. Measurement of fatigue in knee flexor and extensor muscles. **Acta Med Okayama** 54: 85-90.

Macfarlane, D.J., K.L. Chou, Y.H. Cheng and I. Chi. 2006. Validity and normative data for thirty-second chair stand test in elderly community-dwelling hong kong chinese. **Am J Hum Biol** 18: 418-421.

McCarthy, E.K., M.A. Hovrvat, P.A. Holsberg and J.M. Wisenbaker. 2004. Repeated chair stands as a measure of lower limb strength in sexagenarian women. **J Gerontol** 59A: 1207-1212.

Netz, Y., M. Ayalon, A. Dunsky and N. Alexander. 2004. 'The multiple-sit-to-stand' field test for older adults: what does it measure. **Gerontology** 50: 121-126.

Schultz, A.B., N.B. Alexander and J.A. Ashton-Miller. 1992. Biomechanical analyses of rising from a chair. **J Biomech** 25: 1383-1391.

Takai, Y., M. Ohta, R. Akagi, H. Kanehisa, Y. Kawakami and T. Fukunaga. 2009. Sit-to-stand test to evaluate knee extensor muscle size and strength in the elderly: a novel approach. **J Physiol Anthropol** 28: 123-128.

Wretenberg, P.and U.P. Arborelius. 1994. Power and work produced in different leg muscle groups when rising from a chair. **Eur J Appl Physiol Occup Physiol** 68: 413-417.