Peripheral Arteries

Eur J Vasc Endovasc Surg (2023) 65, 521—527

EJVES Open Access

# Sit to Stand Muscle Power Is Related to Functional Performance at Baseline and After Supervised Exercise Training in Patients with Lower Extremity Peripheral Artery Disease

**Stefano Lanzi** [*], **Anina Pousaz, Luca Calanca, Lucia Mazzolai**

Division of Angiology, Heart and Vessel Department, Lausanne University Hospital, Switzerland

**WHAT THIS STUDY ADDS**

Patients with PAD have decreased muscle power, contributing to functional limitations. The instruments to assess muscle power are usually expensive. The sit to stand (STS) is an easy clinical test to assess muscle power in older individuals. This observational study investigated the relationships between baseline STS muscle power and baseline treadmill and functional performance, and quality of life in patients with symptomatic PAD. These relationships were also investigated following supervised exercise training programme. The results showed that STS muscle power was related to common disease related outcomes before and after training, highlighting its clinical value to monitor overall functional status in these individuals.

**Objective:** Patients with peripheral artery disease (PAD) have decreased muscle power, contributing to functional limitations. The sit to stand (STS) is a validated test to assess muscle power in older individuals; however, it has never been investigated in patients with PAD. The relationship between STS muscle power, and common disease related outcomes was evaluated at baseline and following supervised exercise training (SET) in patients with PAD.
**Methods:** This observational study investigated patients with Fontaine stage II. Before and after SET, maximum treadmill walking distance (MWD), functional performance tests (six minute walk, STS, stair climbing, habitual gait speed), and quality of life (Short Form 36 questionnaire) were assessed. Relative (W/kg) STS muscle power was calculated using a validated equation. Multiple regressions models were used.
**Results:** Ninety-five patients with PAD were included (63.1 $\pm$ 12.1 years, 67% male). Relative STS muscle power before: 2.7 W/kg, 95% confidence interval [CI] 2.5 — 2.9; after: 3.3, 95% CI 3.1 — 3.6, MWD before: 367.0 m, 95% CI 302.4 — 431.5; after: 598.4, 95% CI 515.6 — 681.3, six minute walking distance before: 418.3 metres; 95% CI 399.4 — 437.2; after: 468.8; 95% CI 452.7—484.9, stair climbing performance before: 6.8 seconds 95% CI 6.2 — 7.4); after: 5.3; 95% CI 4.9 — 5.7, habitual gait speed before: 1.10 m/s, 95% CI 1.05 — 1.14; after: 1.18, 95% CI 1.14 — 1.22 increased significantly following SET ($p < .001$). Similarly, physical before: 31.4, 95% CI 29.4 — 33.3; after: 35.8, 95% CI 33.9 — 37.7 and mental before: 39.5, 95% CI 37.0 — 42.0; after: 43.1, 95% CI 40.9 — 45.4 component summaries of the SF-36 also increased significantly ($p < .001$). Greater relative STS muscle power at baseline was significantly related to greater baseline treadmill ($\beta < .380$; $p < .002$) and functional ($\beta < .597$; $p < .001$) performance, and quality of life ($\beta < .291$; $p < .050$). Larger increases in relative STS muscle power following SET were associated with greater improvements in functional performance ($\beta < .419$; $p < .009$).
**Conclusion:** The STS test is a valid clinical tool to monitor overall functional status in patients with symptomatic PAD.

**Keywords:** Physical activity, Rehabilitation, Quality of life, Walking performance
Article history: Received 24 March 2022, Accepted 24 December 2022, Available online 31 December 2022


## INTRODUCTION

Lower extremity peripheral artery disease (PAD) is an atherosclerotic vascular disease leading to narrowing and or occlusion of the arteries supplying the legs.[1] PAD has a great impact on walking capacity, physical function, and quality of life.[1–3] Supervised exercise therapy (SET) is a first

* Corresponding author. Division of Angiology, Heart and Vessel Department, Ch. de Mont-Paisible 18-1011 Lausanne, Switzerland.
@ste_lanzi (S. Lanzi).

https://doi.org/10.1016/j.ejvs.2022.12.029

line therapeutic option for the management of patients with symptomatic PAD.[1,4–6] SET is effective in improving treadmill performance and quality of life.[7,8] Changes in functional performance (the rate at which an individual is able to perform a daily functional task) following SET have been poorly investigated.[9]

Patients with PAD have decreased type II fibre cross sectional area, calf skeletal muscle fibre denervation, and decreased maximum lower limb muscle strength compared with controls.[10–12] Further strength deficits occur with the onset of claudication pain.[13] These skeletal muscle changes are associated with functional impairment.[10,14]

Although less investigated, leg muscle power is also impaired in patients with PAD compared with controls.[15] These results are important, since muscle power has been demonstrated to be a stronger predictor of functional limitations than muscle strength in older individuals.[16] Moreover, muscle power declines with age at a faster rate than muscle strength and size.[17] In patients with PAD, reduced leg muscle power contributes to low functional performance.[15] The main difference between muscle strength and power resides in the velocity factor. Indeed, while muscle strength is the ability to overcome resistance, muscle power is the ability to overcome resistance in the shortest period of time (as fast as possible). The stronger relationship observed between muscle power and functional performance may be linked to the velocity factor in generating force that is needed to perform daily life tasks.

The instruments to assess leg muscle power are expensive, requiring technical support. The sit to stand (STS) test is an easy and inexpensive tool to assess the time required to stand and sit as fast as possible five times or the number of repetitions in a given period. Recently, a simple equation to assess relative (W/kg) STS muscle power from STS time performance has been validated.[18] The expression of relative muscle power is judicious, since during most daily life activities people must carry their body mass. STS performance and relative STS muscle power were also related to quality of life.[18]

The associations between STS performance and relative STS muscle power, and walking performance, functional performance, and quality of life have not been investigated in patients with PAD. The first aim of this study was to evaluate the relationships between baseline STS performance and relative STS muscle power, and baseline treadmill performance, functional performance, and quality of life in patients with symptomatic PAD. The second aim was to evaluate the relationships between SET induced changes in STS performance and relative STS muscle power, and changes in treadmill performance, functional performance, and quality of life.

## MATERIALS AND METHODS

### Participants

Patients with lower extremity PAD were investigated (Table 1). Patients were recruited from the Division of Angiology at Lausanne University Hospital, Switzerland. Patients were included in the Angiofit study, an observational cohort of Fontaine stage II men and women with symptomatic PAD participating in the three month SET programme.[19–21] The inclusion criteria of the SET programme were chronic uni- or bilateral lower limb claudication and a resting ankle brachial index (ABI) $\leq$ 0.9 or an ABI decreased by $>$ 20% after exercise.[1] The exclusion criteria were the inability to participate in the SET programme three times per week and critical limb ischaemia (assessed by a vascular physician before SET), and a cardiac contraindication to exercise (assessed by a cardiologist before SET). Compared with previous observations,[19–23] all the patients having an assessment of treadmill performance, functional performance (6 minute walk, sit to stand, stair climbing, and habitual gait speed), and quality of life were included. Patients provided written, voluntary informed consent. The study was approved by the local ethics committee and was conducted according to the Declaration of Helsinki.

### Experimental design

The experimental design was planned as follows: (1) the pre-SET vascular medicine examination and treadmill test; (2) the pre-SET functional assessment; (3) the three month SET programme; (4) the post-SET functional assessment; and (5) the post-SET vascular medicine examination and treadmill test. The SET programme started one to two weeks following the vascular examination, and one to three days after the pre-SET functional assessment. The functional assessments were performed on the same day and patients

**Table 1. Baseline characteristics of 95 patients with symptomatic peripheral artery disease (PAD)**

| Variables | Patients ($n$ = 95) |
|---|---|
| Women | 31 (33) |
| Age – y | 63.1 $\pm$ 12.1 |
| BMI – kg/m$^2$ | 26.9 $\pm$ 5.3 |
| Ankle brachial index | 0.80 $\pm$ 0.20 |
| Toe brachial index | 0.61 $\pm$ 0.20 |
| *Cardiovascular risks factors* | |
| Hypercholesterolaemia | 78 (82) |
| Hypertension | 67 (71) |
| Smoking – current | 49 (52) |
| Smoking – former | 37 (39) |
| Smoking – never | 9 (9) |
| Family history of CVD | 34 (36) |
| Type 1 diabetes | 1 (1) |
| Type 2 diabetes mellitus | 32 (34) |
| Prior arterial revascularisation | 43 (45) |
| *Stenosis location* | |
| Aorto-iliac | 29 (30) |
| Femorodistal | 66 (70) |
| *Ongoing treatment* | |
| Antiplatelet | 89 (94) |
| Antihypertensive | 69 (73) |
| Lipid lowering | 74 (78) |
| Anticoagulant | 10 (11) |
| Antidiabetic | 31 (33) |

Data are presented as mean $\pm$ standard deviation or $n$ (%). BMI = body mass index; CVD = cardiovascular disease.

were allowed to rest between measurements. The following order was always used: six minute walk test, stair climbing test, habitual gait speed, and STS test. The patients were asked to rest well prior to the tests. Following SET, all the assessments were performed at least 48 hours after the last training session.

### Medical history, physical characteristics, and vascular examination

The medical history and physical examination were assessed. Body mass index (BMI), cardiovascular risk factors (tobacco use, dyslipidaemia, type 2 diabetes mellitus, hypertension) and ongoing treatment were recorded. Resting ABI and toe brachial index (TBI) were measured in the supine position.[1]

### Treadmill performance

Pain free walking distance (PFWD) and maximum walking distance (MWD) were determined during a constant speed treadmill test.[6,24] This test was performed at 3.2 km/hour with a 12% slope. However, the speed was adapted depending on patient safety and feasibility, and the same parameters were used before and after SET.

### Functional performance

The six minute walking distance (6MWD) was determined during a six minute walk test.[25] Patients were asked to walk as far as possible within six minutes in an indoor 50 metre corridor. During the test, patients were allowed to stop and lean against the wall. If so, they were instructed to resume walking as soon as they could.

The stair climbing performance was assessed during a stair climbing test.[26] After the cue "ready, set, go!" patients were asked to climb a 12 stair flight as quickly as possible. The height of each stair was 17 cm. Patients were allowed to hold the handrail during the test. The stopwatch was stopped when both of the patient's feet reached the 12th stair, and the time was recorded to the nearest 0.01 second. This test was performed twice, and the average values were considered for analysis.[26]

Habitual gait speed was assessed over a four metre walk. After the cue "ready, set, go!" patients were asked to cover four metres at their habitual walking speed. The time was recorded with a stopwatch to the nearest 0.01 second. This test was performed twice, and the best time of two attempts was chosen for analysis.[27]

The STS test was performed on a standardised armless chair (0.45 metres height).[18] Patients familiarised with the STS test performed one set of five repetitions, followed by a brief resting period. After the cue "ready, set, go!" the patients started to perform STS repetitions. From a sitting position, arms across the chest, patients were asked to stand five times as fast as they could. The stopwatch was stopped immediately after the fifth repetition, and the time was recorded to the nearest 0.01 second. Verbal encouragement was given. Relative (W/kg) STS muscle power was calculated as follows:[18]

relative STS mean power $= (0.9 \times g \times [\text{height} \times 0.5 - \text{chair height}])/(\text{five STS time} \times 0.1)$,where height and chair height are in metres, time is in seconds, and $g$ is gravity.

### Quality of life

The Medical Outcomes Study Short Form 36 (SF-36) was used to evaluate physical and mental health related quality of life.[28] Physical component summary (PCS) and mental component summary (MCS) were computed using weighting coefficients.[29] The Walking Impairment Questionnaire (WIQ) was used to evaluate self perceived walking limitations.[30]

### Supervised exercise training programme

The programme consisted of three weekly training sessions combining two different exercise modalities, strengthening of the lower limbs (once weekly) and Nordic walking (twice weekly), for lasting three months. Each training session lasted up to 60 minutes. A detailed description has been widely reported elsewhere.[19–23] All the training sessions were supervised by a clinical exercise physiologist. In accordance with the guidelines,[5,6,31] the claudication pain intensity during the training sessions was set at moderate to severe on the claudication scale. The rate of perceived exertion (RPE) on Borg's scale was used to monitor the exercise training intensity. The RPE was mainly set between low (9 – 11 on Borg's scale) and moderate (12 – 13 on Borg's scale) intensity. If tolerated, patients also performed at moderate to vigorous intensity (14 – 16 on Borg's scale).

Compliance with the SET programme was defined by the percentage of attended sessions out of the total number of sessions.

### Statistical analysis

Based on previous data,[22] a sample size of 55 patients (power 95%; $\alpha = 5\%$) was needed to detect significant differences in walking performance following SET. Data were analysed with an intention to treat approach. This increases the statistical power and avoids potential selection bias. The first step was to perform multiple imputations for patients who did not complete the training programme. Multiple imputations for missing data were performed to obtain 20 imputed datasets. A fully conditional specification with predictive mean matching was used to simultaneously impute all variables.[32] Baseline anthropometric characteristics, cardiovascular risk factors, vascular parameters, and baseline outcome values were used to impute the datasets.

Thereafter, the normality of the distribution was assessed statistically (Kolmogorov–Smirnov) and visually. Log transformation was performed for non-parametric values. The influence of covariables (age and gender) on the different outcomes was assessed *a priori* with simple linear regressions. Comparisons between before and after SET were assessed using repeated measures analysis of variance adjusted for covariables when appropriate. To assess whether baseline or changes (deltas: post- minus pre-values) in STS performance and relative STS muscle power were related to baseline or changes in treadmill performance, functional performance, and quality of life, simple and multiple regression models were computed. Age and sex were added to the regression models as covariables when appropriate. Multicollinearity was assessed to confirm that the independent variables were not highly correlated with each other. This assumption was tested using variance inflation factor values. These analyses were also performed according to the stenosis location (aorto-iliac ($n = 29$) and femorodistal ($n = 66$) group). The level of significance was set at $p \leq .05$.

SPSS 27 software (IBM Corporation, Armonk, NY) was used to perform all statistical analyses.

## RESULTS

### *Participants*

Ninety-five patients with symptomatic PAD were included. Of those, 22 patients (23%) did not complete the SET programme. The reasons for stopping SET were worsening of claudication symptoms ($n = 4$), endovascular revascularisation required during SET ($n = 4$), schedule conflict with work ($n = 2$), feeling anxious about participating during the pandemic period ($n = 3$) and other reasons not related to SET ($n = 9$). The attendance rate for SET was 79.9%.

### *Sit to stand performance and muscle power, treadmill and functional performance, and quality of life*

STS performance and relative STS muscle power significantly increased following SET (Table 2). Both obstructive aorto-iliac and femorodistal groups significantly improved STS performance and relative STS muscle power following SET, with no significant difference between groups (Supplementary Table S1). PFWD, MWD, 6MWD, stair climbing performance, habitual gait speed, PCS, MCS, WIQ distance, speed, and stair climbing scores significantly improved after SET (Table 2). The *a posteriori* statistical power was $\geq$ 82%, except for the WIQ distance (68%).

### *Relationships between baseline sit to stand performance and muscle power, and baseline treadmill and functional performance, and quality of life*

Greater STS performance (lower STS time) and relative STS muscle power at baseline were significantly related to greater baseline PFWD, MWD, 6MWD, stair climbing performance, habitual walking speed, PCS, WIQ distance, WIQ speed, and WIQ stair climbing scores (Table 3). There was no significant relationship between baseline STS performance and relative STS muscle power, and baseline MCS (Table 3). Similar results were found when patients were analysed according to the stenosis location (Supplementary Table S2).

### *Relationships between sit to stand performance and muscle power changes, and changes in treadmill and functional performance, and quality of life*

Larger increases in STS performance (lower STS time) and relative STS muscle power following SET were associated with greater improvements in 6MWD, stair climbing performance, and habitual gait speed (Table 4). There was no significant relationship between changes in STS performance and relative STS muscle power, and changes in treadmill performance and quality of life following SET (Table 4). Similar results were found when patients were analysed according to the stenosis location (Supplementary Table S3).

**Table 2. Sit to stand (STS) performance and muscle power, treadmill performance, functional performance, and quality of life before and after the supervised exercise training (SET) of 95 patients with symptomatic peripheral artery disease (PAD)**

| Variable | Before SET ($n = 95$) | After SET ($n = 95$) | $p$ value |
|---|---|---|---|
| *STS performance and muscle power* | | | |
| STS – s | 15.0 (12.9–17.1) | 12.2 (10.4–14.1) | <.001 |
| Relative STS muscle power – W/kg | 2.7 (2.5–2.9) | 3.3 (3.1–3.6) | <.001 |
| *Treadmill performance* | | | |
| Pain free walking distance – m | 109.0 (81.4–136.6) | 152.8 (133.0–172.6) | <.001 |
| Maximum walking distance – m | 367.0 (302.4–431.5) | 598.4 (515.6–681.3) | <.001 |
| *Functional performance* | | | |
| 6 minute walking distance* – m | 418.3 (399.4–437.2) | 468.8 (452.7–484.9) | <.001 |
| Stair climbing test* – s | 6.8 (6.2–7.4) | 5.3 (4.9–5.7) | <.001 |
| Habitual gait speed – m/s | 1.10 (1.05–1.14) | 1.18 (1.14–1.22) | <.001 |
| *Quality of life* | | | |
| Physical component score* – % | 31.4 (29.4–33.3) | 35.8 (33.9–37.7) | <.001 |
| Mental component score – % | 39.5 (37.0–42.0) | 43.1 (40.9–45.4) | .001 |
| WIQ distance score* – % | 62.2 (57.8–66.6) | 67.8 (64.1–71.5) | .002 |
| WIQ speed score – % | 55.6 (50.7–60.5) | 63.7 (59.8–67.6) | .001 |
| WIQ stair climbing score – % | 60.1 (55.6–64.6) | 67.4 (63.7–71.1) | .001 |

Data are presented as mean and 95% CI. WIQ = walking impairment questionnaire, scored on a 0 (worse score) to 100 (best score) scale.
* Adjusted for sex.

**Table 3. Relationship between baseline sit to stand (STS) performance and relative STS muscle power, and baseline treadmill performance, functional performance, and quality of life of 95 patients with symptomatic peripheral artery disease (PAD)**

| Baseline values | STS time performance ($n$ = 95) | | Relative STS muscle power ($n$ = 95) | |
|---|---|---|---|---|
| | β standardised coefficient | $p$ value | β standardised coefficient | $p$ value |
| Pain free walking distance – m | −.29 | .005 | .32 | .002 |
| Maximum walking distance – m | −.36 | <.001 | .38 | <.001 |
| 6 minute walking distance* – m | −.53 | <.001 | .60 | <.001 |
| Stair climbing test*,† – s | .49 | <.001 | −.58 | <.001 |
| Habitual gait speed*,† – m/s | −.29 | .002 | .43 | <.001 |
| Physical component score – % | −.29 | .005 | .25 | .015 |
| Mental component score* – % | −.13 | .23 | .17 | .12 |
| WIQ distance score – % | −.30 | .004 | .29 | .004 |
| WIQ speed score – % | −.30 | .003 | .28 | .005 |
| WIQ stair climbing score – % | −.24 | .022 | .20 | .050 |

WIQ = walking impairment questionnaire, scored on a 0 (worse score) to 100 (best score) scale.
* Adjusted for age.
† Adjusted for sex.

**Table 4. Relationship between changes in sit to stand (STS) performance and relative STS muscle power, and changes in treadmill performance, functional performance, and quality of life following supervised exercise training of 95 patients with symptomatic peripheral artery disease (PAD)**

| Delta values | Δ STS performance ($n$ = 95) | | Δ relative STS muscle power ($n$ = 95) | |
|---|---|---|---|---|
| | β standardised coefficient | $p$ value | β standardised coefficient | $p$ value |
| Pain free walking distance – m | −.11 | .29 | .070 | .50 |
| Maximum walking distance – m | −.067 | .52 | .054 | .60 |
| 6 minute walking distance* – m | −.36 | <.001 | .42 | <.001 |
| Stair climbing test* – s | .39 | <.001 | -.45 | <.001 |
| Habitual gait speed – m/s | −.24 | .019 | .27 | .009 |
| Physical component score* – % | .070 | .94 | .024 | .82 |
| Mental component score – % | −.017 | .87 | .037 | .72 |
| WIQ distance score* – % | .064 | .53 | .005 | .96 |
| WIQ speed score – % | .051 | .62 | -.035 | .74 |
| WIQ stair climbing score – % | −.091 | .38 | .10 | .32 |

WIQ = walking impairment questionnaire, scored on a 0 (worse score) to 100 (best score) scale.
* Adjusted for sex.

### *Physical characteristics and vascular parameters*

BMI before: 26.9 kg/m$^2$, 95% CI 25.8 – 28.0; after: 27.4, 95% CI 26.4 – 28.4, $p$ = .10, ABI before: 0.80 (95% CI 0.75 – 0.84); after: 0.79, 95% CI 0.76 – 0.82, $p$ = .62, and TBI before: 0.61, 95% CI 0.57–0.65; after: 0.60, 95% CI 0.57 – 0.63, $p$ = .83 were unchanged following SET.

## DISCUSSION

The main findings showed that (1) baseline STS performance and relative STS muscle power were related to baseline treadmill and functional performance, and quality of life; (2) larger increases in STS performance and relative STS muscle power following SET were associated with greater improvements in functional performance only. There was no significant relationship between changes in STS performance and relative STS muscle power, and changes in treadmill performance and quality of life.

The present study showed that SET improved functional performance assessed by several functional tests. As previously reported,[9] performance based tests of physical function are understudied following SET in patients with PAD. The results showed that SET improves STS performance, relative STS muscle power, stair climbing performance, and habitual gait speed, which are all representative of functional daily life activities. The mean increase in habitual walking speed was + 0.08 m/s, which is similar to the minimum clinically important difference for substantial change in walking speed following SET in patients with PAD.[33] These results highlight the importance of exercise therapy to improve functional performance. This is clinically important since improved functional mobility may predict functional independence in these individuals.[34]

The results presented herein showed that greater STS performance and relative STS muscle power at baseline were significantly related to greater baseline treadmill (PFWD, MWD) and overground (6MWD) performance, stair climbing performance, habitual walking speed, physical health related quality of life, and WIQ scores. In contrast, mental health related quality of life was not related to baseline STS performance or relative STS muscle power. Taken together, these results are in line with previous observations showing that muscle power is linked to functional performance in patients with PAD.[15] It is likely that muscle power is a more important determinant of physical rather than mental health related quality of life, which is mainly composed of self reported vitality, social and emotional functioning.[18] The results also showed that larger increases in STS performance and relative STS muscle power following SET were associated with greater improvements in functional performance only. Indeed, changes in STS performance and relative STS muscle power after SET were related to changes in overground walking and stair climbing performance, and habitual gait speed. Since it has been shown that improved walking performance correlates with lower limb strength gain following resistance training in patients with PAD,[35] the results of the present investigation further extend these associations on leg muscle power. Although the mechanisms underlying the effects of muscle power gain on functional performance remain to be clearly determined,[36] it is possible that better muscle fibre recruitment, which may also induce a reduction in the energy cost during walking, may be mainly implicated.[35,36] In contrast, these results showed no significant relationship between changes in STS performance and relative STS muscle power, and changes in treadmill performance and quality of life. The lack of significance between muscle power and treadmill performance may be directly linked to characteristics of the test. Indeed, relative to the six minute walk, the maximum treadmill test is less representative of daily life walking and sub-maximal daily life activities.[37] Therefore, since muscle power has been found to be a strong predictor of functional abilities,[16] it is likely that better associations were found with more functional assessments of performance. Finally, improvement in muscle power following a three month SET may occur before self perception of greater improvements in quality of life. It is likely that longer training programmes may induce better associations between muscle power and self perceived quality of life. Further studies are needed to better assess this speculation.

These results feature important clinical implications. First, since larger increases in muscle power following SET were associated with greater improvements in functional performance, further investigations are needed regarding the specific effects of high velocity power oriented resistance training on functional status in patients with PAD. Indeed, previous meta-analyses have shown that this type of training may induce better improvements in muscle power and functional performance than traditional (slow velocity) strength training in older individuals.[38–40] The explosive (high velocity) movements performed during the power oriented resistance training may be more effective in improving daily life functional performance, especially in activities where intense and rapid movements are essential, such as counteracting a forward fall, climbing steps, brisk walking, or crossing the road. Second, because of its easy administration, the STS test should be used to monitor the training response following and during the exercise rehabilitation programmes. This may allow investigation of the time course evolution of overall physical function and, subsequently, improve the training guidance. This is in line with previous validated tools aiming to improve monitoring and training individualisation in these individuals.[41]

The first limitation of this study was that missing data were replaced using multiple imputations. However, the results did not substantially change when analyses were performed without multiple imputations (Supplementary Table S4 and S5). In addition, since the sample size was small, this may improve the statistical power. Second, this study lacks a control group. Patients participated in the clinical SET programme and were recruited during routine vascular visits. For ethical considerations, all patients willing to participate in SET must be included. Third, patients had a moderate to high walking performance and results may not be generalised to patients with more severe PAD.

In conclusion, these results suggest that the STS test may provide a practical and easy clinical tool to monitor overall functional status before and after exercise interventions in patients with symptomatic PAD.

## CONFLICT OF INTEREST STATEMENT AND FUNDING

None.

## APPENDIX A. SUPPLEMENTARY DATA

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ejvs.2022.12.029.

## REFERENCES

1 Aboyans V, Ricco JB, Bartelink MEL, Bjorck M, Brodmann M, Cohnert T, et al. Editor's Choice – 2017 ESC guidelines on the diagnosis and treatment of peripheral arterial diseases, in collaboration with the European Society for Vascular Surgery (ESVS). *Eur J Vasc Endovasc Surg* 2018;**55**:305–68.
2 Liles DR, Kallen MA, Petersen LA, Bush RL. Quality of life and peripheral arterial disease. *J Surg Res* 2006;**136**:294–301.
3 McDermott MM, Liu K, Greenland P, Guralnik JM, Criqui MH, Chan C, et al. Functional decline in peripheral arterial disease: associations with the ankle brachial index and leg symptoms. *JAMA* 2004;**292**:453–61.
4 Frank U, Nikol S, Belch J. 5 Conservative treatment for PAD – risk factor management. *Vasa* 2019;**48**:1–12.
5 Harwood A, Pymer S, Ingle L, Doherty P, Chetter I, Parmenter B, et al. Exercise training for intermittent claudication: a narrative review and summary of guidelines for practitioners. *BMJ Open Sport Exercise Med* 2020;**6**:e000897.
6 Treat–Jacobson D, McDermott MM, Bronas UG, Campia U, Collins TC, Criqui MH, et al. Optimal exercise programs for patients with peripheral artery disease: a scientific statement from the American Heart Association. *Circulation* 2019;**139**:e10–33.
7 Lane R, Harwood A, Watson L, Leng GC. Exercise for intermittent claudication. *Cochrane Database Syst Rev* 2017;**12**:CD000990.
8 Parmenter BJ, Dieberg G, Smart NA. Exercise training for management of peripheral arterial disease: a systematic review and meta–analysis. *Sports Med* 2015;**45**:231–44.

9 Parmenter BJ, Raymond J, Fiatarone Singh MA. The effect of exercise on fitness and performance−based tests of function in intermittent claudication: a systematic review. *Sports Med* 2013;**43**:513−24.
10 McDermott MM, Criqui MH, Greenland P, Guralnik JM, Liu K, Pearce WH, et al. Leg strength in peripheral arterial disease: associations with disease severity and lower-extremity performance. *J Vasc Surg* 2004;**39**:523−30.
11 McDermott MM, Hoff F, Ferrucci L, Pearce WH, Guralnik JM, Tian L, et al. Lower extremity ischemia, calf skeletal muscle characteristics, and functional impairment in peripheral arterial disease. *J Am Geriatr Soc* 2007;**55**:400−6.
12 Regensteiner JG, Wolfel EE, Brass EP, Carry MR, Ringel SP, Hargarten ME, et al. Chronic changes in skeletal muscle histology and function in peripheral arterial disease. *Circulation* 1993;**87**:413−21.
13 Schieber MN, Hasenkamp RM, Pipinos II , Johanning JM, Stergiou N, DeSpiegelaere HK, et al. Muscle strength and control characteristics are altered by peripheral artery disease. *J Vasc Surg* 2017;**66**:178−86.
14 McDermott MM, Tian L, Ferrucci L, Liu K, Guralnik JM, Liao Y, et al. Associations between lower extremity ischemia, upper and lower extremity strength, and functional impairment with peripheral arterial disease. *J Am Geriatr Soc* 2008;**56**:724−9.
15 McDermott MM, Guralnik JM, Albay M, Bandinelli S, Miniati B, Ferrucci L. Impairments of muscles and nerves associated with peripheral arterial disease and their relationship with lower extremity functioning: the InCHIANTI Study. *J Am Geriatr Soc* 2004;**52**:405−10.
16 Bean JF, Leveille SG, Kiely DK, Bandinelli S, Guralnik JM, Ferrucci L. A comparison of leg power and leg strength within the InCHIANTI study: which influences mobility more? *J Gerontol A Biol Sci Med Sci* 2003;**58**:728−33.
17 Reid KF, Pasha E, Doros G, Clark DJ, Patten C, Phillips EM, et al. Longitudinal decline of lower extremity muscle power in healthy and mobility-limited older adults: influence of muscle mass, strength, composition, neuromuscular activation and single fiber contractile properties. *Eur J Appl Physiol* 2014;**114**:29−39.
18 Alcazar J, Losa-Reyna J, Rodriguez-Lopez C, Alfaro-Acha A, Rodriguez-Manas L, Ara I, et al. The sit-to-stand muscle power test: an easy, inexpensive and portable procedure to assess muscle power in older people. *Exp Gerontol* 2018;**112**:38−43.
19 Lanzi S, Boichat J, Calanca L, Aubertin P, Malatesta D, Mazzolai L. Gait changes after supervised exercise training in patients with symptomatic lower extremity peripheral artery disease. *Vasc Med* 2021;**26**:259−66.
20 Lanzi S, Boichat J, Calanca L, Mazzolai L, Malatesta D. Supervised exercise training improves 6 min walking distance and modifies gait pattern during pain-free walking condition in patients with symptomatic lower extremity peripheral artery disease. *Sensors (Basel)* 2021;**21**:7989.
21 Lanzi S, Calanca L, Berchtold A, Mazzolai L. Improvement in 6-minute walking distance after supervised exercise training is related to changes in quality of life in patients with lower extremity peripheral artery Disease. *J Clin Med* 2021;**10**:3330.
22 Calanca L, Lanzi S, Ney B, Berchtold A, Mazzolai L. Multimodal supervised exercise significantly improves walking performances without changing hemodynamic parameters in patients with symptomatic lower extremity peripheral artery disease. *Vasc Endovascular Surg* 2020;**54**:605−11.
23 Ney B, Lanzi S, Calanca L, Mazzolai L. Multimodal supervised exercise training is effective in improving long term walking performance in patients with symptomatic lower extremity peripheral artery disease. *J Clin Med* 2021;**10**:2057.
24 Hiatt WR, Hirsch AT, Regensteiner JG, Brass EP. Clinical trials for claudication. Assessment of exercise performance, functional status, and clinical end points. Vascular Clinical Trialists. *Circulation* 1995;**92**:614−21.
25 ATS Committee on Proficiency Standards for Clinical Pulmonary Function Laboratories. ATS statement: guidelines for the six-minute walk test. *Am J Respir Crit Care Med* 2002;**166**: 111−7.
26 Bean JF, Kiely DK, LaRose S, Alian J, Frontera WR. Is stair climb power a clinically relevant measure of leg power impairments in at-risk older adults? *Arch Phys Med Rehabil* 2007;**88**: 604−9.
27 Guralnik JM, Simonsick EM, Ferrucci L, Glynn RJ, Berkman LF, Blazer DG, et al. A short physical performance battery assessing lower extremity function: association with self−reported disability and prediction of mortality and nursing home admission. *J Gerontol* 1994;**49**:M85−94.
28 Ware Jr JE, Sherbourne CD. The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. *Med Care* 1992;**30**:473−83.
29 Roser K, Mader L, Baenziger J, Sommer G, Kuehni CE, Michel G. Health-related quality of life in Switzerland: normative data for the SF-36v2 questionnaire. *Qual Life Res* 2019;**28**:1963−77.
30 Coyne KS, Margolis MK, Gilchrist KA, Grandy SP, Hiatt WR, Ratchford A, et al. Evaluating effects of method of administration on Walking Impairment Questionnaire. *J Vasc Surg* 2003;**38**:296−304.
31 Treat−Jacobson D, McDermott MM, Beckman JA, Burt MA, Creager MA, Ehrman JK, et al. Implementation of supervised exercise therapy for patients with symptomatic peripheral artery disease: a science advisory from the American Heart Association. *Circulation* 2019;**140**:e700−10.
32 van Buuren S. Multiple imputation of discrete and continuous data by fully conditional specification. *Stat Methods Med Res* 2007;**16**: 219−42.
33 Rahman H, Pipinos II , Johanning JM, Casale G, Williams MA, Thompson JR, et al. Claudicating patients with peripheral artery disease have meaningful improvement in walking speed after supervised exercise therapy. *J Vasc Surg* 2021;**74**: 1987−95.
34 McDermott MM, Liu K, Ferrucci L, Tian L, Guralnik JM, Liao Y, et al. Decline in functional performance predicts later increased mobility loss and mortality in peripheral arterial disease. *J Am Coll Cardiol* 2011;**57**:962−70.
35 Parmenter BJ, Mavros Y, Ritti Dias R, King S, Fiatarone Singh M. Resistance training as a treatment for older persons with peripheral artery disease: a systematic review and meta−analysis. *Br J Sports Med* 2019;**54**:452−61.
36 McDermott MM, Dayanidhi S, Kosmac K, Saini S, Slysz J, Leeuwenburgh C, et al. Walking exercise therapy effects on lower extremity skeletal muscle in peripheral artery disease. *Circ Res* 2021;**128**:1851−67.
37 McDermott MM, Guralnik JM, Criqui MH, Liu K, Kibbe MR, Ferrucci L. Six-minute walk is a better outcome measure than treadmill walking tests in therapeutic trials of patients with peripheral artery disease. *Circulation* 2014;**130**:61−8.
38 Balachandran AT, Steele J, Angielczyk D, Belio M, Schoenfeld BJ, Quiles N, et al. Comparison of power training vs traditional strength training on physical function in older adults: a systematic review and meta-analysis. *JAMA Netw Open* 2022;**5**: e2211623.
39 Byrne C, Faure C, Keene DJ, Lamb SE. Ageing, muscle power and physical function: a systematic review and implications for pragmatic training interventions. *Sports Med* 2016;**46**:1311−32.
40 Tschopp M, Sattelmayer MK, Hilfiker R. Is power training or conventional resistance training better for function in elderly persons? A meta-analysis. *Age Ageing* 2011;**40**:549−56.
41 Manfredini F, Conconi F, Malagoni AM, Manfredini R, Mascoli F, Liboni A, et al. Speed rather than distance: a novel graded treadmill test to assess claudication. *Eur J Vasc Endovasc Surg* 2004;**28**:303−9.