Increasing intensity during treadmill walking does not adversely affect walking pattern or quality in newly-ambulating stroke patients: an experimental study

Author

Kuys, Suzanne, Brauer, Sandra, Ada, Louise, Russell, Trevor

Published

2008

Journal Title

Australian Journal of Physiotherapy

Rights statement

© 2008 Australian Physiotherapy Association. The attached file is reproduced here in accordance with the copyright policy of the publisher. Use hypertext link to access the publisher's website.

Downloaded from

http://hdl.handle.net/10072/20802

Link to published version

http://ajp.physiotherapy.asn.au/AJP/vol_54/1/volume54_number1.cfm

Griffith Research Online

https://research-repository.griffith.edu.au

Increasing intensity during treadmill walking does not adversely affect walking pattern or quality in newly-ambulating stroke patients: an experimental study

Suzanne S Kuys[1, 2, 3], Sandra G Brauer[3], Louise Ada[4] and Trevor G Russell[3]

[1]Griffith University [2]Princess Alexandra Hospital [3]The University of Queensland [4]The University of Sydney
Australia

Question: Does walking on a treadmill at increasing intensities adversely affect walking pattern or reduce walking quality during treadmill walking? Are any changes influenced by walking ability? **Design**: A within-participant, repeated measures experimental study. **Participants**: 18 individuals with a first stroke who were undergoing inpatient rehabilitation. **Intervention**: Walking on a treadmill at intensities of 30%, 40%, 50% and 60% heart rate reserve in the one session. **Outcome measures**: During treadmill walking practice, walking pattern was measured as linear and angular kinematics while walking quality was measured using the Rivermead Gait Analysis scale and a visual analogue scale. **Results**: Walking on the treadmill at 60% heart rate reserve, step length of the paretic limb was 0.05 m (95% CI 0.01 to 0.10) longer, step length of the non-paretic limb was 0.09 m (95% CI 0.05 to 0.12) longer, and hip flexion at mid swing was 4 degrees (95% CI 1 to 6) greater than at 30% heart rate reserve. At 60% heart rate reserve, hip and knee extension at mid stance were respectively 3 and 4 degrees more flexed than at 30% heart rate reserve. Walking ability did not affect changes in walking pattern. Walking quality did not change with increasing treadmill intensity. **Conclusion**: Walking on a treadmill at increasing intensity did not adversely affect walking pattern or reduce walking quality in newly-ambulating stroke patients. This study adds some support for the inclusion of walking on a treadmill at higher intensities in rehabilitation for newly-ambulating stroke patients. **[Kuys SS, Brauer SG, Ada L, Russell TG (2008) Increasing intensity during treadmill walking does not adversely affect walking pattern or quality in newly-ambulating stroke patients: an experimental study. *Australian Journal of Physiotherapy* 54: 49–54]**

Key words: Gait, Rehabilitation, Stroke, Treadmill, Physiotherapy

Introduction

Cardiorespiratory fitness is emerging as an impairment requiring attention during inpatient rehabilitation after stroke (Kilbreath and Davis 2005). Optimal strategies to address this impairment have not yet been determined. A recent systematic review found promising but limited evidence for the effect of cardiorespiratory fitness training on cardiorespiratory fitness after stroke, and stated that further research was required regarding the content and training modes of cardiorespiratory fitness training (Saunders et al 2004).

To retrain cardiorespiratory fitness as part of the rehabilitation program, physiotherapists must be prepared to increase the intensity of practice. A target training intensity of 40–60% heart rate reserve is recommended for the very unfit (ACSC 2000, Gordon et al 2004). On average, current physiotherapy practice for stroke patients is carried out at intensities of less than 25% heart rate reserve (Kuys et al 2006). When practising lower limb activities capable of raising the heart rate, such as climbing stairs, it rises to intensities of between 25% and 35% heart rate reserve (Kuys et al 2006). This equates to less than 5 minutes spent at the target training intensity (Mackay-Lyons and Makrides 2002a) for increasing cardiorespiratory fitness. One reason for the failure of physiotherapy rehabilitation to achieve intensities capable of inducing a cardiorespiratory training effect is that the focus at this stage is mostly on decreasing impairments, such as muscle weakness and loss of dexterity, and optimising performance during activities (Kilbreath & Davis 2005).

Treadmills are one tool available to physiotherapists that could be used to retrain cardiorespiratory fitness. In fact this has been done successfully with chronic stroke survivors able to walk (Macko et al 1997; Macko et al 2001; Macko et al 2005). Treadmill walking seems to be of most benefit in people with stroke who are able to walk (Moseley et al 2005), with faster treadmill walking speeds associated with greater improvements in walking (Pohl et al 2002). But there is a wide variation in the walking ability of people after stroke. In those people with faster walking speeds, a more normal walking pattern has been observed (Olney et al 1994, Roth et al 1997). It is reasonable to suggest that for those with slower walking speeds, the walking pattern and quality may deteriorate more than in those with faster walking speeds if walking is challenged.

Stroke patients undergoing rehabilitation can participate safely in exercise reaching appropriate intensities provided screening is undertaken (Macko et al 1997, Dobrovolny et al 2003, Gordon et al 2004, Kilbreath and Davis 2005, Macko et al 2005). But there appears to be some reluctance amongst clinical physiotherapists to increase the intensity of practice for stroke patients undergoing rehabilitation due to a perception that the quality of the practice will be reduced (Davies 1999). Only one study has begun to address this issue where the addition of treadmill training to Bobath intervention resulted in no worse gait quality than Bobath intervention alone after 6 weeks. However, participants in this randomised controlled trial had mild levels of disability, had to be able to walk at least 12 m to be eligible for inclusion, and used 15% body weight support during the intervention (Eich et al 2004).

Therefore, the research questions for this study were:

1. Does walking on a treadmill at increasing intensities adversely affect walking pattern or reduce walking quality during treadmill walking?
2. Are any changes influenced by walking ability?

Method

Design

A within-participant repeated-measures experimental study of treadmill walking practice was carried out. Newly-ambulating stroke patients undergoing inpatient rehabilitation walked on a treadmill at four increasing intensities as measured by heart rate within one session. Participants underwent a pre-test session prior to the commencement of the study. During this session, walking ability was measured and participants were familiarised with the treadmill which involved walking on the treadmill until they reported feeling comfortable. This took on average 15 minutes (range 5–40). Additional familiarisation sessions were provided as necessary, with 11 participants requiring more than one session. Walking pattern was measured at each intensity during the treadmill walking. Institutional ethics committees approved this study and informed consent was obtained from all participants. All participants had medical clearance for participation in the study.

Participants

Patients admitted consecutively to a tertiary rehabilitation unit of a large metropolitan hospital in Brisbane, Australia, were eligible for inclusion if they: were admitted following their first stroke, had a primary diagnosis of stroke, were medically stable, were able to consent to participate in this study, were referred for physiotherapy, had a Motor Assessment Scale Item 5 (walking) score of at least 3; and were able to walk on a treadmill without physical assistance. Participants were assessed for inclusion by an experienced neurological physiotherapist. Participants therefore were able to walk at least three metres with or without a walking aid without standby help. Patients were excluded if they had any cardiovascular problems that limited their participation in physiotherapy, had other neurological or musculoskeletal conditions affecting their gait, or if their gait velocity was greater than 1.23 m/sec for women and 1.33 m/sec for men (Bohannon 1997). Demographic and clinical information about participants obtained from the medical record included: gender, date of birth, date and side of stroke, and any medications which may affect heart rate such as beta-blockers. Walking ability was measured using Item 5 of the Motor Assessment Scale (Carr et al 1985) by an experienced physiotherapist in order to stratify participants into low and high walkers.

Intervention

Following a warm up period, subjects walked at intensities corresponding to 30%, 40%, 50%, and 60% of heart rate reserve (%HRR) calculated using Karvonen's formula (Activity HR = [% (HR age predicted maximal–HR rest)]–HR rest) (ACSC 2000) reaching steady state for each intensity level. Resting heart rate was recorded after five minutes of quiet sitting via a portable heart rate monitor and heart rate was then measured continuously throughout the intervention. The calculation of heart rate age predicted maximal was adjusted (85% [220–age]) for participants taking beta-blocker medication to accommodate the heart rate-lowering effect of this type of medication as has been done previously (MacKay-Lyons and Makrides, 2002a). As stroke patients undergoing rehabilitation reach an average exercise intensity during advanced walking activities (such as treadmill walking) close to 30% heart rate reserve (Kuys et al 2006), this was chosen as our starting point. Rest periods were provided as required. A treadmill safety stop cord and an assistant were available at all times for safety. A loosely applied harness without any body weight support was also available if participants wished to use it. If at any time participants wished to cease walking on the treadmill they were able to do so. Treadmill speed, distance walked, and a Borg rating of perceived exertion (Borg 1982) was recorded.

Outcome measures

Walking pattern during treadmill walking was measured using a 2-dimensional webcam kinematic software analysis application developed at the University of Queensland for telerehabilitation research. This application has been shown to be a valid method for measuring joint angles and has a high level of inter- ($ICC_{2,1} = 0.97$ to > 0.99) and intra- ($ICC = 0.93$ to > 0.99) rater reliability (Russell 2007). Ten gait cycles were videotaped at each of the four heart rate intensities via two cameras which were positioned to view the sagittal and posterior aspect of the patient. Video was captured at 25 frames per second at 640 × 480 pixel resolution. Frames that best represented heel strike, mid stance, heel off, toe off, and mid-swing gait phases were selected for analysis. Linear kinematics of paretic and non-paretic limb step length and paretic limb foot clearance during mid swing; and angular kinematics of sagittal plane hip, knee and ankle joint angles and frontal plane pelvic level, hip abduction and trunk lateral flexion were measured.

Walking quality during treadmill walking was determined by observation of the video footage for each participant at each of the four intensities. The footage was scored according to the Rivermead Visual Gait Analysis scale and a 100-mm visual analogue scale (Pomeroy et al 2003). During treadmill walking, participants were encouraged to hold the handrail; therefore the upper limb items of the Rivermead Visual Gait Analysis scale were not included, resulting in a maximum total score of 54. Video files of the ten gait cycles (72 in total: 4 files for 18 participants) were placed in a random order (for participant and intensity level) by an off-site investigator using a computerised random number generator program. Two experienced neurological physiotherapists, one of whom was the first author, the second having no involvement with the study or participants, rated each file on the Rivermead Visual Gait Analysis and the visual analogue scale. No other additional information was provided to the second physiotherapist. Agreement was reached between the two raters regarding the interpretation of the scales prior to the observation of any video files. Following separate viewings of the first five video files, the two physiotherapists met to discuss issues with the scales.

Table 1. Mean (SD) walking pattern during treadmill walking at each intensity and mean (95% CI) difference between lowest and highest intensities.

Walking pattern	Intensities				Difference between intensities
	30% HRR	40% HRR	50% HRR	60% HRR	60% minus 30% HRR
Linear kinematics (m)					
P step length	0.35 (0.1)	0.34 (0.12)	0.39 (0.11)	0.40 (0.13)	0.05 (0.01 to 0.10)
NP step length	0.33 (0.11)	0.37 (0.12)	0.40 (0.11)	0.42 (0.1)	0.09 (0.05 to 0.12)
Foot clearance during mid swing	0.02 (0.01)	0.03 (0.01)	0.02 (0.01)	0.03 (0.01)	0.01 (–0.08 to 0.40)
Angular kinematics* *(°)*					
Knee extension at heel strike	–19 (13)	–18 (9)	–19 (10)	–18 (8)	1 (–5 to 7)
Knee extension at mid stance	–11 (7)	–14 (6)	–14 (8)	–15 (7)	–4 (–6 to –2)
Hip extension at mid stance	–5 (6)	–7 (6)	–7 (6)	–8 (7)	–3 (–6 to 1)
Hip extension at push off	5 (9)	7 (8)	7 (7)	7 (6)	2 (–3 to 6)
Knee flexion at toe-off	46 (10)	48 (13)	50 (12)	51 (13)	5 (0 to 9)
Ankle plantarflexion at toe-off	33 (9)	32 (11)	32 (9)	31 (11)	–2 (–8 to 4)
Hip flexion at mid swing	23 (10)	24 (8)	27 (8)	27 (10)	4 (1 to 6)

HRR = heart rate reserve, P = paretic, NP = nonparetic; * where anatomical position = 0

Discussion of actual scores for these participants on the rating scales did not occur.

Data analysis

Preliminary analysis of the first 10 participants revealed that to have an 80% chance of detecting a 5% difference in paretic and nonparetic limb step length, hip and knee angle at mid stance, hip angle at push off and mid swing between lowest and highest intensity, at a significance of $p = 0.05$, 12–15 participants were required.

Repeated measures analysis of variance within-participant comparison of heart rate intensity (30%, 40%, 50%, 60% heart rate reserve) was used to test whether walking pattern (linear and angular kinematics) was different across the four heart rate intensities. Mean difference (95% CI) between the highest and lowest intensities were reported. Nonparametric repeated measure analysis (Friedman's Test) was used to investigate the effect of increasing intensity during the treadmill walking practice on walking quality (Rivermead Visual Gait Analysis and visual analogue scale). Walking quality measured by Rivermead Visual Gait Analysis was compared across all treadmill intensities with visual analogue scale using Spearman's correlation coefficient for nonparametric variables.

Participants were then divided into two groups according to walking ability based on their scores on Item 5 of the Motor Assessment Scale. Participants who scored 3 or 4 were grouped as having low walking ability, and those who scored 5 or 6, high walking ability. Independent t-tests were used to describe differences between the two groups. Repeated measures analysis of variance was used to test whether walking ability affected the difference in walking pattern across the four intensities (interaction of intensity [30%, 40%, 50% or 60% heart rate reserve] × walking ability [low and high]). Nonparametric repeated measure analysis (Friedman's Test) was used to investigate the interaction of intensity (30%, 40%, 50%, 60% heart rate reserve) and walking ability (low vs high). Statistical significance was set at $p = 0.05$.

Results

Characteristics of participants

Eighteen people with a first stroke participated in this study. The average age of participants was 62 years (SD 12) with 10 (56%) being male and 9 (50%) having suffered a left-sided stroke. Participants were on average 73 (SD 50) days after stroke. They walked overground at 0.65 m/s (range 0.3 to 1.04) indicating mild to moderate disability. Grouping participants based on their score on Item 5 of the MAS resulted in 9 participants each with low and high walking ability.

Compliance with intervention

All subjects completed all four intensities. The average velocity of the treadmill belt increased with increasing heart rate intensity as was expected. At 30% heart rate reserve, average treadmill velocity was 0.53 m/s (SD 0.20), increasing to 0.64 (SD 0.30), 0.72 (SD 0.30), and 0.83 m/s (SD 0.30) at 40%, 50%, and 60% heart rate reserve respectively. Borg rating of perceived exertion increased from a median score of 8 to 11 between 30% and 60% heart rate reserve, indicating a very light intensity. No adverse incidents occurred.

Effect of intensity on walking pattern during treadmill walking

Mean (SD) linear and angular kinematics recorded during treadmill walking at each intensity are presented in Table 1. Table 1 also illustrates the mean (95% CI) difference between the highest and lowest intensity. During treadmill walking with increasing intensity, paretic ($p < 0.01$) and non paretic ($p < 0.01$) limb step length increased, knee extension at midstance reduced ($p < 0.01$) and hip flexion at mid swing increased ($p = 0.01$). There was no change in the other linear

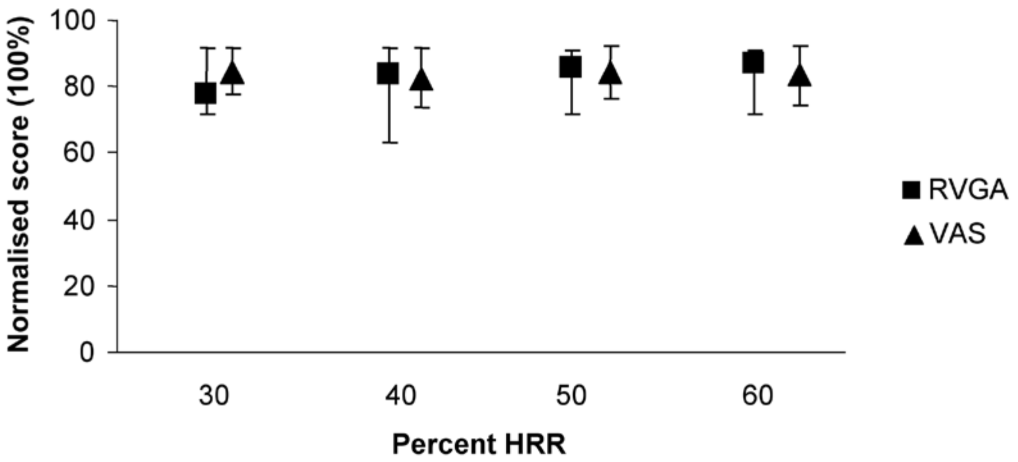

Figure 1. Normalised median (IQR) scores for Rivermead Visual Gait Analysis scale and normalised mean (SD) visual analogue scale score across four intensities. 100% = normal walking, HRR = heart rate reserve.

or angular kinematics. At 60% heart rate reserve, step length of the paretic limb was 0.05 m (95% CI 0.01 to 0.10) longer, step length of the non-paretic limb was 0.09 m (95% CI 0.05 to 0.12) longer, and hip flexion at mid swing was 4 degrees (95% CI 1 to 6) greater than at 30% heart rate reserve. Hip and knee extension during mid stance was 3 and 4 degrees more flexed respectively walking at 60% heart rate reserve compared with 30% heart rate reserve.

Effect of intensity on walking quality during treadmill walking

Normalised median (IQR) Rivermead Visual Gait Analysis and mean (SD) visual analogue scale data during treadmill walking at each intensity are presented in Figure 1. Data were highly correlated ($r > 0.72$). No significant change in walking quality was detected with increasing intensity of treadmill walking ($p > 0.05$).

Effect of walking ability on difference in walking pattern at different intensities

Walking ability of participants did not affect the changes found in walking pattern during treadmill walking at increasing intensities ($p > 0.05$).

Discussion

This study demonstrated that walking on a treadmill at increasing intensities had little effect on walking pattern or quality during treadmill walking in stroke patients undergoing rehabilitation.

Reduced step length is commonly reported after stroke (Woolley 2001) and in this study both paretic and non paretic limb step lengths ranged from 35 to 42 cm (Table 1). Between the lowest and highest intensity, paretic and non-paretic limb step length increased 5 cm and 9 cm respectively during treadmill walking. Previous studies have also reported increased stride length with faster treadmill velocities (Wagenaar and Beek 1992, Hesse et al 2001).

Angular kinematic measures during treadmill walking at increasing intensities have not previously been investigated. Reduced knee extension at mid stance and hip flexion at mid swing are common deviations from normal observed during walking after stroke (Moore et al 1993, Moseley et al 1993). This study found an increase in hip flexion during mid swing and a reduction of knee extension at mid stance and of hip extension between the highest and lowest intensity. The greater flexion of the paretic limb in stance at the highest intensity could impact on walking quality. However, these changes were small, 3 and 4 degrees, and during treadmill walking physiotherapists could not discern any difference in walking quality at the highest compared with the lowest intensity. As the values fall within the normal range for stance and swing phase (Kerrigan et al 1998, Winter et al 1990), it is probable they have little clinical significance.

The influence of walking ability of the participants was investigated in this study. Stroke survivors with better walking ability, ie, with faster walking speeds, have greater independence and a more normal appearance (Bohannon 1987) with fewer deviations associated with a typical hemiplegic walking pattern (Olney 1994). Therefore, it seemed reasonable to question whether walking ability would influence the quality of treadmill walking. However, the concerns held by some physiotherapists that increasing the intensity of treadmill walking may harm walking quality were not supported by this study. This supports the findings from a previous study which also reported no adverse effect on walking quality of a treadmill intervention at higher intensities (Eich 2004).

The intensities used in this study reflect the minimum intensity required to achieve a cardiorespiratory training effect for the deconditioned or unfit (ACSC 2000). Cardiorespiratory fitness can be reduced by approximately 50% as early as one month after stroke (MacKay-Lyons and Makrides 2002b). Although it improves, it remains well below expected normative values at 6 months after stroke (MacKay-Lyons and Makrides 2004) due to a combination of the presence of cardiovascular comorbidities, age-related decline, and lack of physical activity subsequent to the stroke (Kilbreath and Davis 2005).

Increasing the intensity of practice has some potential benefits. Walking speed has been shown to discriminate between those stroke survivors able or not able to ambulate within the community following discharge from rehabilitation (Lord et al 2004). Older adults admitted for geriatric rehabilitation with walking speeds greater than 0.35 m/s were more likely to be independent in activities of daily living (Potter et al 1995). Therefore, increasing intensity of walking practice early in rehabilitation may have benefits both during and following rehabilitation after stroke.

The intensity of treadmill walking investigated in this study may not be applicable to all stroke survivors, as this intensity could result in the development of or recurrence of pre-existing musculoskeletal problems or a cardiovascular event. Adhering to the guidelines for ceasing exercise, using a handrail during treadmill walking, providing sufficient familiarisation, and moderating treadmill speed (Gordon et al 2004) are appropriate safeguards for clinical use (MacKay-Lyons and Howlett 2005). Although the average age of the participants in this study was 62 years, more than half (61%) were over 65 years, and yet they experienced no adverse events and coped with the highest intensity.

Measures in this study were chosen because they were appropriate for a clinical environment yet valid and reliable. Greater accuracy of walking pattern could have been afforded if a 3D motion analysis system was used to collect kinematic data. However, the 2D system used in this study has been validated for clinical use (Russell 2007). Likewise, greater accuracy of maximal heart rate would have been possible if it had been measured rather than calculated. However, although treadmill (MacKay-Lyons and Makrides 2002b) and cycle ergometer (Kelly et al 2003) maximal and submaximal tests have been developed and used safely with people with stroke, they require expensive and cumbersome equipment, significant space and personnel, and strict adherence to testing protocols (ACSC 2000) which are not routinely available in the clinic. In addition, blood lactate levels could have been used to ensure that aerobic intensities were reached during treadmill walking. However, the facilities to undertake this measurement are also not routinely available in the clinic and heart rate has been demonstrated to be an accurate measure of energy expenditure or exercise intensity (Strath et al 2000) and cardiorespiratory fitness (Plasqui and Westerterp 2005).

In summary, this study, conducted on a typical group of stroke patients undergoing rehabilitation, found that treadmill walking at increasing intensities did not adversely affect the quality of the walking practice. It adds to the growing evidence that including a cardiorespiratory retraining component in the rehabilitation of those stroke patients able to walk will not result in a poorer quality of walking. Further research is required to investigate if longer durations of treadmill walking at the intensities investigated in this study are capable of improving cardiorespiratory fitness and walking capacity.

Correspondence: Suzanne Kuys, School of Physiotherapy and Exercise Science, Griffith University, Australia. Email: s.kuys@griffith.edu.au

Acknowledgements: Suzanne Kuys is supported by NHMRC Public Health Postgraduate Scholarship Grant ID: 456308. The authors would also like to acknowledge the support of the staff and patients of the Geriatric and Rehabilitation Unit of the Princess Alexandra Hospital, without whom this study would not have been feasible.

References

American College of Sports Medicine (2000) *ACSM's Guidelines for Exercise Testing and Prescription*, 6th ed. Philadelphia: Lippincott Williams & Wilkins.

Bohannon RW (1997) Comfortable and maximum walking speed of adults aged 20–79 years: reference values and determinants. *Age and Ageing* 26: 15–19.

Bohannon RW (1987) Gait performance of hemiparetic stroke patients: selected variables. *Archives of Physical Medicine and Rehabilitation* 68: 777–781.

Borg GA (1982) Psychophysical bases of perceived exertion. *Medicine and Science in Sports and Exercise* 14: 377–381.

Carr JH, Shepherd RB, Nordholm L, Lynne D (1985) Investigation of a new motor assessment scale for stroke patients. *Physical Therapy* 65: 175–180.

Davies PM (1999) Weight-supported treadmill training. *Neurorehabilitation and Neural Repair* 3:167–169.

Dobrovolny CL, Ivey FM, Rogers MA, Sorkin JD, Macko RF (2003) Reliability of treadmill exercise testing in older patients with chronic hemiparetic stroke. *Archives of Physical Medicine and Rehabilitation* 84: 1308–1312.

Eich HJ, Mach H, Werner C, Hesse S (2004) Aerobic treadmill plus Bobath walking training improves walking in subacute stroke: a randomized controlled trial. *Clinical Rehabilitation* 18: 640–651.

Gordon NF, Gulanick M, Costa F, Fletcher G, Franklin BA, Roth EJ, Shephard T (2004) Physical activity and exercise recommendations for stroke survivors: an American Heart Association scientific statement from the Council on Clinical Cardiology. *Stroke* 35: 1230–1240.

Hesse S, Werner C, Paul T, Bardeleben A, Chaler J (2001) Influence of walking speed on lower limb muscle activity and energy consumption during treadmill walking of hemiparetic patients. *Archives of Physical Medicine and Rehabilitation* 82: 1547–1550.

Kelly JO, Kilbreath SL, Davis GM, Zeman B, Raymond J (2003) Cardiorespiratory fitness and walking ability in subacute stroke patients. *Archives of Physical Medicine and Rehabilitation* 84: 1780–1785.

Kerrigan DC, Todd MK, Della Croce U, Lewis A, Lipsitz MD, Collins JJ (1998) Biomechanical gait alterations independent of speed in the healthy elderly: evidence for specific limiting impairments. *Archives of Physical Medicine and Rehabilitation* 79: 317–322.

Kilbreath SL, Davis GM (2005) Cardiorespiratory fitness after stroke. In KM Refshauge, L Ada, E Ellis (Eds) *Science based Rehabilitation: Theories into Practice.* Edinburgh: Butterworth-Heinemann pp. 131–151.

Kuys SS, Brauer SG, Ada L (2006) Routine physiotherapy does not induce a cardiorespiratory training effect post-stroke, regardless of walking ability. *Physiotherapy Research International* 12: 219–227.

Lord SE, McPherson K, McNaughton HK, Rochester L, Weatherall M (2004) Community ambulation after stroke: how important and obtainable is it and what measures appear predictive? *Archives of Physical Medicine and Rehabilitation* 85: 234–239.

MacKay-Lyons MJ, Howlett J (2005) Exercise capacity and cardiovascular adaptations to aerobic training early after stroke. *Topics in Stroke Rehabilitation* 12: 31–44.

MacKay-Lyons MJ, Makrides L (2002a) Cardiovascular stress during a contemporary stroke rehabilitation program: is the intensity adequate to induce a training effect? *Archives of Physical Medicine and Rehabilitation* 83: 1378–1383.

MacKay-Lyons MJ and Makrides L (2002b) Exercise capacity early after stroke. *Archives of Physical Medicine and Rehabilitation* 83: 1697–1702.

MacKay-Lyons MJ and Makrides L (2004) Longitudinal changes in exercise capacity after stroke. *Archives of Physical Medicine and Rehabilitation* 85: 1608–1612.

Macko RF, De Souza CA, Trett LD, Silver KH, Smith GV, Anderson PA, Tomoyasu N, Gorman P, Dengel DR (1997) Treadmill aerobic exercise training reduces the energy expenditure and cardiovascular demands of hemiparetic gait in chronic stroke patients. *Stroke* 28: 326–330.

Macko RF, Macko RF, Smith GV, Dobrovolny CL, Sorkin JD, Goldberg AP, Silver KH (2001) Treadmill training improves fitness reserve in chronic stroke patients. *Archives of Physical Medicine and Rehabilitation* 82: 879–884.

Macko RF, Ivey FM, Forrester LW, Hanley D, Sorkin JD, Katzel LI, Silver KH, Goldberg AP (2005) Treadmill exercise rehabilitation improves ambulatory function and cardiovascular fitness in patients with chronic stroke: a randomized, controlled trial. *Stroke* 36: 2206–2211.

Moseley AM, Stark A, Cameron ID, Pollock A (2005) Treadmill training and body weight support for walking after stroke. *Cochrane Database of Systematic Reviews* 2005, Issue 4. Art. No.: CD002840. DOI: 10.1002/14651858.CD002840.pub2.

Moseley A, Wales A, Herbert R, Schurr K, Moore S (1993) Observation and analysis of hemiplegic gait: stance phase. *Australian Journal of Physiotherapy* 39: 259–267.

Moore S, Schurr K, Wales A, Moseley A, Herbert R (1993) Observation and analysis of hemiplegic gait: swing phase. *Australian Journal of Physiotherapy* 39: 271–278.

Olney SJ, Griffin MP, McBride ID (1994) Temporal, kinematic, and kinetic variables related to gait speed in subjects with hemiplegia: a regression approach. *Physical Therapy* 74: 872–885.

Plasqui G, Westerterp KR (2005) Accelerometry and heart rate as a measure of physical fitness: proof of concept. *Medicine and Science in Sports and Exercise* 37: 872–876.

Pohl M, Mehrholz J, Ritschel C, Ruckriem S (2002) Speed-dependent treadmill training in ambulatory hemiparetic stroke patients: a randomized controlled trial. *Stroke* 33: 553–558.

Pomeroy VM, Pramanik A, Sykes L, Richards J, Hill E (2003) Agreement between physiotherapists on quality of movement rated via videotape. *Clinical Rehabilitation* 17: 264–272.

Potter JM, Evans AL, Duncan G (1995) Gait speed and activities of daily living function in geriatric patients. *Archives of Physical Medicine and Rehabilitation* 76: 997–999.

Roth EJ, Merbitz C, Mroczek K, Dugan SA, Suh WW (1997) Hemiplegic gait: relationships between walking speed and other temporal parameters. *American Journal of Physical Medicine and Rehabilitation* 76: 128–137.

Russell TG (2007) Goniometry via the internet [summary]. *Australian Journal of Physiotherapy* 53: 136.

Saunders DH, Greig CA, Young A, Mead GE (2004) Physical fitness training for stroke patients. *Cochrane Database of Systematic Reviews* 2004, Issue 1. Art. No.: CD003316. DOI: 10.1002/14651858.CD003316.pub2.

Strath SJ, Swartz AM, Bassett DR Jr, O'Brien WL, King GA, Ainsworth BE (2000) Evaluation of heart rate as a method for assessing moderate intensity physical activity. *Medicine and Science in Sports and Exercise* 32: S465–470.

Wagenaar RC, Beek WJ (1992) Hemiplegic gait: a kinematic analysis using walking speed as a basis. *Journal of Biomechanics* 25: 1007–1015.

Winter DA, Patla AE, Walt F, Walt SE (1990) Biomechanical walking pattern changes in the fit and healthy elderly. *Physical Therapy* 70: 340–348.

Woolley SM (2001) Characteristics of gait in hemiplegia. *Topics in Stroke Rehabilitation* 7: 1–18.

Statement regarding registration of clinical trials from the Editorial Board of *Australian Journal of Physiotherapy*

This journal now requires registration of clinical trials. All clinical trials submitted to *Australian Journal of Physiotherapy* must have been registered prospectively in a publicly-accessible trials register. We will accept any register that satisfies the International Committee of Medical Journal Editors requirements. Authors must provide the name and address of the register and the trial registration number on submission.