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# The Effect of Knee Flexion Contracture Following Total Knee Arthroplasty on the Energy Cost of Walking

Michael T. Murphy, BPhty, BHMS [a], Tina L. Skinner, PhD, BAppSci (HMS-Ex Sci) (Hons), GCHigherEd [b], Andrew G. Cresswell, BEd, MSc, Med Dr (Neuroscience) [b], Ross W. Crawford, D.Phil (Oxon), MBBS, FRACS (Orth) [c], Simon F. Journeaux, BSc, MBBS, FRCS, FRACS (Orth) [a], Trevor G. Russell, PhD, BPhty [d]

[a] *Mater Research, Mater Health Services, South Brisbane, Australia*
[b] *School of Human Movement Studies, The University of Queensland, St Lucia, Australia*
[c] *School of Biomedical Engineering, Queensland University of Technology, Brisbane, Australia*
[d] *School of Health and Rehabilitation Sciences, The University of Queensland, St Lucia, Australia*

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ABSTRACT

This study evaluated the energy cost of walking ($C_w$) with knee flexion contractures (FC) simulated with a knee brace, in total knee arthroplasty (TKA) recipients (n = 16) and normal controls (n = 15), and compared it to baseline (no brace). There was no significant difference in $C_w$ between the groups at baseline but TKA recipients walked slower ($P = 0.048$) and with greater knee flexion in this condition ($P = 0.003$). Simulated FC significantly increased $C_w$ in both groups (TKA $P = 0.020$, control $P = 0.002$) and this occurred when FC exceeded 20° in the TKA group and 15° in the controls. Reported perceived exertion was only significantly increased by FC in the control group (control $P < 0.001$, TKA $P = 0.058$). Simulated knee FCs less than 20° do not increase $C_w$ or perceived exertion in TKA recipients.



Achieving optimal knee flexion is generally recognised as one of the key goals following total knee arthroplasty (TKA) due to its critical role in many routine daily activities [1,2]. Comparatively little attention has been devoted to the effects of limited knee extension [3–5]. A persistent flexion contracture (FC) however can be a greater impairment than limited knee flexion [4] with poor long term outcomes [6], and may cause abnormal stresses on both knees [3,5]. Harato et al. [5] simulated a FC with an adjustable brace in healthy older women and found a unilateral contracture of 15° led to mechanical overload of both lower limbs in standing and during the stance phase of gait. In the context of a TKA population these excessive forces may have adverse implications for knee implant durability or disease progression in the contralateral arthritic knee [5].

In normal stance the line of the ground reaction force between the floor and the centre of gravity lies close to the axes of the hip and knee joints, minimising the muscular effort required to maintain an upright position [7]. With a FC, this line lies posterior to the knee joint, tending to further flex the knee and increasing the demand on lower limb musculature [7–9]. Perry et al. [9] demonstrated the force required to stabilise the knee rises from 0 newtons (N) at full extension to 500 N at 15°. The quadriceps eccentrically control knee flexion in the early stance phase of gait. As the knee extends the ground reaction force moves anterior to the knee providing a passive extension moment that decreases demand on the quadriceps. A FC will delay this anterior translation and has been shown to increase vastus lateralis, gluteus maximus and soleus electromyographic activity, with vastus lateralis increasing 1300% at a 40° FC simulation [10].

Increased muscular recruitment in combination with other lower limb and trunk adaptations will increase the exertion or cost of walking ($C_w$) [8]. The $C_w$ will increase with gait impairments such as hip or knee arthritis [11], after fusion of the hip or ankle [12], in elderly individuals with limitations in hip range of motion [13] and with complete immobilisation of the knee [14] but little is known about the $C_w$ in a TKA population. Mattsson et al. [15] compared the post-operative $C_w$ of unicompartmental knee arthroplasty and TKA recipients. They found that the $C_w$ was unchanged in TKA patients and concluded that they may have retained a poor pre-operative gait pattern. Few studies have evaluated the effect of knee FC. Duffy et al. [16] used adjustable knee braces to simulate bilateral FC's in a normal paediatric population for application to children with neurological disorders. They found the increased $C_w$ to be primarily determined by the braces as they were relatively cumbersome for their subjects. One other study cited in the literature used a hinged brace unilaterally on normal adult subjects and reported greater knee contracture

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Reprint requests: Michael T. Murphy, BPhty, BHMS, Mater Research, Mater Health Services, Raymond Terrace, South Brisbane, 4101, Australia.

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increased $C_w$ and decreased gait speed [17]. Scant detail however was provided on the subjects, protocol or the statistical significance of the findings.

TKA patients are reported to have a high prevalence of systemic comorbidity with one large trial reporting over 40% of patients having ASA (American Society of Anesthesiologists) scores of III–IV (severe systemic illness) [18]. If knee FC increases the exertion of walking the risk of cardiovascular events could be increased. No studies to date have investigated the effect of FC on the $C_w$ in a TKA population.

The primary aim of this study was to determine whether a knee FC imposes a physiological burden and increases $C_w$ and, if the threshold for the increases in $C_w$ was at 15° as found in other studies. A second aim of the study was to evaluate whether similar effects would be evident in a normal population. We hypothesised that: (1) $C_w$ would increase significantly with FC, (2) this difference would occur at 15°, and (3) FC will cause a relatively greater $C_w$ in TKA recipients than in a normal population.

## Materials and Methods

### *Participants*

Male and female participants over 50 years of age who had undergone successful TKA by two of the authors (SFJ, RWC) at least six months prior to testing were recruited for this study. An equivalent group of normal participants who had not undergone TKA were also recruited. Successful TKA was defined as achieving an Oxford Knee Score [19] of ≥40 (possible range of scores is 12–48 with 48 reflecting the best possible score). All participants were required to have a range of knee motion of ≤5° FC (full knee extension was defined as 0°) and ≥90° knee flexion, in both knees. Participants who walked with an aid, had a history of falls or medical or orthopaedic co-morbidity which would impair normal gait or prevent them from completing submaximal exercise testing were excluded. Thirty-one participants volunteered for the study; 16 TKA recipients (9 male, 7 female) and 15 normal participants (7 male, 8 female). The mean duration from surgery for the TKA group was 22.1 ± 17.0 months. Participants were instructed to abstain from smoking for at least 12 hours prior to testing, and to avoid large meals, caffeine or strenuous exercise for four hours before testing. Adherence to abstinence guidelines were confirmed with pre-testing interview. The study was granted approval by the institutional human ethical review board and all participants provided written informed consent.

### *Procedure*

Gas, ventilatory and kinematic parameters were measured while participants walked at their customary walking speed (CWS) on a motor-driven treadmill (Fig. 1). The effect of different magnitudes of simulated FC was assessed by comparing the specific outcome measures from five stages of walking with an adjustable hinged knee brace (T-Scope, Breg Inc., CA, USA) to those when walking without the brace as the baseline condition. Brace settings were 10°, 20°, 30° and 40° restrictions from full knee extension, and an unrestricted setting. The order of the six walking stages was randomised using a computer generated sequence of numbers to minimise any systematic effect of familiarisation or fatigue. The physiological and perceived effects of wearing the brace was also determined by comparing outcomes in the unrestricted brace condition to baseline.

Passive knee flexion and extension were measured with a universal goniometer using the following anatomical landmarks; greater trochanter, lateral malleolus and lateral epicondyle [20]. Participants were familiarized to the treadmill with a knee brace fitted at the 20° knee flexion setting. Overground CWS was then determined with the average speed calculated from triplicate measures of the

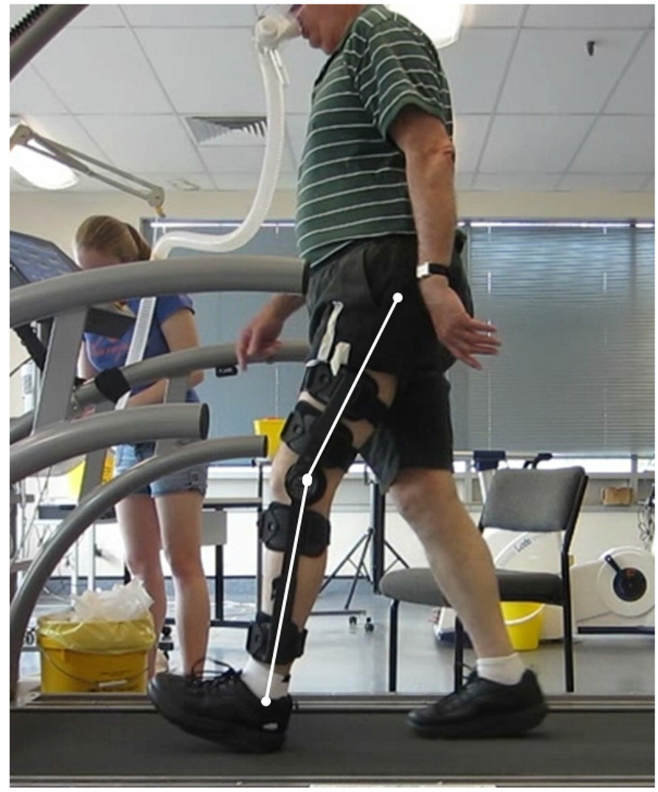

**Fig. 1.** A photograph illustrating testing set-up with gas collection apparatus applied to a participant walking on the treadmill during a 40° brace restriction setting. The magnitude of the simulated FC is depicted.

participant's preferred walking pace over six meters. This brace restriction was chosen to reduce the risk of participants finding their unrestricted CWS difficult to maintain at the largest FC simulation, thus ensuring a constant speed for all increments. All participants completed four minutes of familiarisation on the treadmill wearing the knee brace and gas collection apparatus. Treadmill speed was set to the calculated overground CWS and participants were encouraged to walk normally without holding onto the hand rails. For participants inexperienced with treadmill walking a second familiarisation period was provided until the participant reported they were feeling confident. During familiarisation participants were instructed they could hold onto the side hand rail if they preferred, but to minimise variability during testing conditions they would need to continue to do so for all walking conditions.

### *Oxygen Consumption and Metabolic Calculations*

Oxygen consumption ($VO_2$) and carbon dioxide output ($VCO_2$) were collected breath-by-breath and averaged over 15 s intervals using on-line gas analysers (ParvoMedics, TrueOne 2400, Sandy, UT, USA) and a turbine ventilometer (Morgan, Model 096, Kent, UK). Immediately prior to each test, the gas analysers were calibrated using certified calibration gases and the volume turbine sensor calibrated using a 3 l syringe. Resting $VO_2$ and $VCO_2$, heart rate (HR), respiratory rate (RR) and respiratory exchange ratio (RER) were collected as the participants sat quietly for five minutes prior to the familiarisation period. Measurement of these physiological parameters were repeated during each walking stage for 3–4 minutes until a metabolic steady state was achieved (plateaus of $VO_2$ and HR were observed) at which point a further minute of gas was collected for analysis. Immediately following each stage participants were asked for their rating of perceived exertion (RPE) according to the Borg scale (a 15 point scale from 6–20 where a rating of 7 equates to very light exertion, 13 is