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Biomechanical assessment of gait in below-knee walking casts

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Abstract

The introduction of modern synthetic casting bandages for splinting of fractures and soft tissue injuries has allowed the development of new casting techniques. Casts can be constructed with a greater degree of function so that controlled motion and stabilisation can be provided within the same cast. This study has shown that a very efficient gait can be achieved with modern synthetic bandages, if they are correctly applied. The authors have compared the gait of volunteer subjects fitted respectively with below-knee walking casts constructed from a rigid glass fibre bandage and a flexible glass fibre bandage which is reinforced. These casts were wrapped so that minimal amounts of bandage were used whilst appropriate strength and stiffness was provided. The temporal and spatial factors of cast gait were not statistically different from normal gait. The cast gait was found to be slightly more asymmetrical (dominant versus non-dominant leg) when a cast was worn and there was also a greater Physiological Cost Index (PCI). The flexible bandage has some advantages compared with the rigid bandage as normal footwear can be worn, the casts are more comfortable and they could be removed with shears, obviating the need for a power saw.

Introduction

Following trauma and injury to the limbs causing fracture of a long bone, it was the practice to immobilise the joint above and below the affected region with a cast. This is so that alignment, control of rotation, correct anatomical position and pain relief are achieved. In fractures and injuries affecting joints, the limb segments above and below the joint are immobilised. However, it is now established that the beneficial effects of rest following injury or trauma can have a deleterious effect on surrounding tissues resulting in dystrophy and atrophy if prolonged beyond 7-10 days (Berg and Tesch, 1996; Berg *et al.*, 1997; Klein *et al.*, 1982). Muscle mass and muscle function decreases, ligaments, tendons and the joint capsule are weakened and shortened, and cartilage can develop degenerative changes. Moreover maintaining muscle tone contributes to normal circulation (Williams and Goldspink, 1978). The maintenance of nutrition on soft tissues and the preferred orientation of collagen fibres has been shown to exist when functional joint motion is permitted (Woo *et al.*, 1987). Functional treatment of femoral fractures such as cast bracing has been shown to promote healing of fractures at a much faster rate than prolonged immobilisation by traction. Micromovement at the fracture site has been shown to promote healing of fractures by increasing blood flow in bone and by efficient remodelling (Kenwright and Goodship, 1985). However, many factors are implicated in the biological response of tissues that have been damaged, such as pain, the degree of trauma, duration of immobilisation etc. It is logical to expect that where function is allowed, as compared to a non-functional situation, the rehabilitation phase will be shorter.

Plaster of Paris (PoP) bandage applied in the form of a cast has been the mainstay of conservative management of fractures and soft

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tissue injuries for over 130 years and is designed to immobilise the joints rigidly. PoP casts are heavy, bulky and brittle and do not allow functional loading and controlled activity during healing. Modern synthetic casting materials comprising a knitted fabric bandage impregnated with a polyurethane resin (e.g. Scotchcast, 3M Healthcare, Leicestershire, England) are more versatile materials with improved mechanical properties and have significant benefits during application and removal (Wytch *et al.*, 1990[a]). Most below-knee walking casts (BKWCs) fabricated from synthetic bandages are applied to provide rigid ankle immobilisation in a similar way to PoP and similarly affect the biomechanics of gait.

The effect of a rigid BKWC on gait has been reported in numerous studies (Nuzzo, 1983[a]; Nuzzo 1983[b]; Hullin and Robb, 1991; Pratt *et al.*, 1986; Hellberg *et al.*, 1987; Wytch *et al.*, 1990[b]; Hamzeh *et al.*, 1988). Rigid ankle immobilisation does not allow the foot to plantarflex after heel strike and foot flat is delayed. The ankle is unable to dorsiflex after mid-stance and there is early rotation of the foot on the metatarsal heads. Consequently, there is an increase in the vertical displacement of the knee centre and its maximum excursion occurs after heel off. There is also an abrupt inflexion of the knee pathway (Pratt *et al.*, 1986). However, in order to achieve a more natural gait to compensate for these effects a cast shoe or sole is recommended (Nuzzo, 1983[a]). This allows progression of the leg over the stationary foot which is unable to dorsiflex due to the rigidity of the cast. A shoe with a cushioned heel to tilt the cast so that the knee centre is ahead of the ankle at mid-stance reduces this disability. Nuzzo (1983[a]) also states that much of the disability associated with wearing a BKWC is a result of the treatment rather than the disease.

To produce a functional cast whilst maintaining stabilisation of the injured limb requires a cast with the correct amount of strength and stiffness. The strength and stiffness can easily be increased by adding more layers of bandage but this makes the cast bulky and cumbersome. The stiffness is determined not only by thickness but also by shape. Curves or corrugations can significantly stiffen a cast. The natural curves of the body can be used to advantage when higher stiffness is required and moulding the cast can increase its stiffness. Adding reinforcement to specific regions of the cast increases both its strength and stiffness. Reinforcing the casts at specific points rather than wrapping extra rolls of bandage is more economical of materials and casts are also quicker to apply and to remove.

A technique described by Schuren (1994) uses a flexible glass fibre bandage (Softcast) which is reinforced with rigid layers of synthetic material (Scotchcast) so that both stabilisation and controlled motion can be provided within the same cast (Combicast). When wrapped in the form of a BKWC this type of cast attempts to give the patient a more natural gait and allows normal footwear to be worn. Both Scotchcast and Softcast are knitted glass fibre bandages impregnated with a polyurethane resin. However, the resins differ in their composition so that Softcast is significantly more flexible than the other glass fibre bandages (Schuren, 1994).

In this study the authors compared the gait of healthy volunteer subjects when fitted with below-knee walking casts constructed from a flexible reinforced cast (Combicast) with that when fitted with the conventional type of rigid synthetic bandage (Scotchcast). A minimal amount of material compatible with providing both stabilisation and allowing controlled motion was applied in both cases in order to assess the functional benefits of different casting methods and materials. The volunteers were divided into two groups and given the treatment appropriate for a closed, undislocated, ankle fracture. Volunteer subjects were used so that a high degree of activity would be attempted and because they provide less variability than a patient group with fractures.

Biomechanical measurements during gait

Force platform

The study of foot-ground reaction forces is important in the identification and evaluation of gait abnormalities and has been used in numerous studies. Force platforms are commonly used for this purpose and measure the three orthogonal forces between the foot and the ground (Begg *et al.*, 1990). In order to record ground reaction forces a Kistler, Type 9281B, multi-component force platform system was used running Bioware analysis software (Kistler Instruments, Hants, England). The signals from the force platform were sampled at a rate of

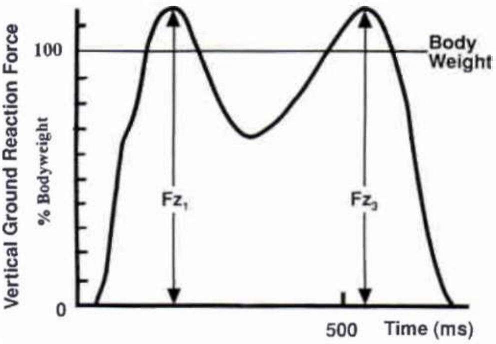


Fig. 1 shows a typical graph of the foot-ground reaction forces during normal gait. The two peak values (Fz_1 and Fz_3) were compared in this study.

1kHz. The force platform data was exported from Bioware from further analysis using Microsoft Excel (Microsoft Corporation, USA).

Aberdeen Video Vector System

The Aberdeen Video Vector System (AVVS) is a hybrid system that includes both kinetic and kinematic aspects of human locomotion (Begg *et al.*, 1990). The output of the AVVS comprises a video image of the subject with the resultant GRF vector, acquired from the Kistler force platform superimposed onto the subject in real time (Fig. 2). Also displayed on the video image are the magnitudes of the three orthogonal forces and a frame counter recorded every 20 milliseconds (50Hz). Gait can be recorded in both the coronal and sagittal planes. In this study only videotape data were analysed.

Gait symmetry indices

Symmetrical human gait occurs when there is complete agreement of the external kinetic and kinematic parameters of the left and right legs. This will rarely, if ever, occur given the complexity of the human body. Hertzog *et al.* (1989) devised a method for quantifying the degree of asymmetry in the foot-ground reaction forces, the stance time and the step and stride lengths in normal gait. The symmetry index was calculated by using Equation 1 and will have a mean value of zero for symmetrical gait. Equation 2 calculates the upper and lower limit limits such that 95% of all symmetry indices obtained from a gait variable associated with normal gait are within these limits.

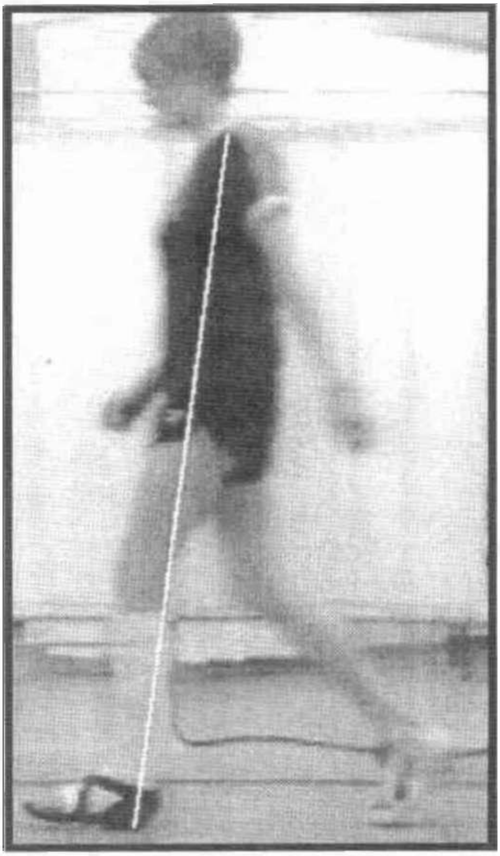
$$\textit{Symmetry Index (SI)} = \frac{X_D - X_N}{0.5(X_D + X_N)}\ 100\% \quad \text{Eq.1}$$

where X_D = gait variable recorded for dominant leg
X_N = gait variable recorded for non-dominant leg

Upper and lower limits of symmetry indices were calculated for baseline values using the following equation:

$$SI_{ul} = 0 \pm t_{df\,(0.05)}.\ SD \quad \text{Eq.2}$$

where $t_{df(0.05)}$ = critical value of t-distribution
df = number of subjects – 1 (i.e. the number of degrees of freedom)



Fx=8N Fy=60N Fz=91% of bodyweight

Fig. 2 shows a typical real time display of a volunteer fitted with a rigid cast and a cast shoe using the Aberdeen Video Vector System. The forces in the mediolateral, anteroposterior and vertical directions are represented by the subscripts x, y and z respectively.

The SIs of cast gait were then compared against SI_{ul} to determine if there was any difference in the symmetry of gait when wearing a cast.

Physiological Cost Index (PCI)

Normal human locomotion is extremely economical in terms of energy expenditure and few other useful activities can be accomplished at a lower net energy cost than walking. Wheelchair propulsion requires somewhat less energy than normal locomotion since two of the major energy consuming factors of normal gait, vertical and horizontal oscilliation of the centre of gravity are eliminated. Pathological gait or gait deviations are usually characterised by increased energy costs often resulting from inefficient use of muscular energy in body movements. A measure of energy expenditure therefore provides an objective assessment of the efficiency of a person's gait. A satisfactory and practicable measurement of energy expenditure is by means of heart rate monitoring. It has been shown that for a given individual the increase in heart rate during exercise is linearly related to the work load (Astrand and Rodahl, 1970).

Heart rate can be significantly affected by factors other than work-load. Emotional stress, in particular, can invoke a cardiovascular response. Other factors include illness and medication, effects of food, alcohol and tobacco, environmental temperature and walking speed (Astrand and Rodahl, 1970; Hamzeh *et al.,* 1988). For these reasons test conditions must be carefully controlled. No food or cigarettes should be taken within 2 hours prior to the test, and heavy physical exercise should be avoided during this period. Alcohol should be avoided for 24 hours before testing.

In any individual, heart rate is affected by speed of walking, and comparisons of speed and heart rate have been used by a number of researchers in their studies on energy expenditure (Blessey, 1978; Davies, 1977; Rose *et al.,* 1985; Rose *et al.,* 1990; Waters *et al.,* 1983; Waters and Lunsford, 1985; Waters *et al.,* 1988). Many studies have shown that monitoring walking speed in conjunction with the measurement of heart rate as a means of assessing energy expenditure has been consistently reproducible (McGregor, 1981; Waters *et al.,* 1988). It has also been shown that the preferred walking speed (self-selected), for an individual, corresponds closely with that at which the energy cost is a minimum (Bard and Ralston 1959; McGregor, 1981; Hellberg *et al.,* 1987).

The Physiological Cost Index (PCI) was developed by McGregor (1981), as a measure of the efficiency of gait. It is defined as the difference between the walking heart rate, H_W, and the resting heart rate, H_R, divided by the speed of walking and is expressed in terms of heart beats per metre (bt/m) walked.

$$\textit{Physiological Cost Index (PCI)} = \frac{H_W - H_R}{\textit{Walking Speed}} \qquad \textbf{Eq.3}$$

Previous studies have found the mean value of the PCI in healthy adults to be 0.35bt/m and ranges from 0.11 to 0.66bt/m (McGregor, 1981; Waters *et al.,* 1988).

The heart rate can be reliably recorded during walking using a Polar heart rate monitor (HRM). The Polar HRM is a lightweight, portable microprocessor manufactured by Polar Electro Oy, Professorintie 5, SF-90440, Finland. The monitor consists of a chest band, containing two contact electrodes and a lithium battery powered electronic ECG sensor and radio frequency transmitter, and a battery powered wrist watch receiver. The band is fastened round the chest, just below the level of the nipples, and the electrodes detect the electrical impulse of the heart. The heart rate can be recorded continuously every 5 seconds, displayed on the wrist watch face and stored in the receiver memory. The data can be uploaded to a personal computer using a serial port connection, processed and displayed on the computer screen using the Polar Edge software and the mean heart rate calculated.

Experimental procedure

Eight (8) healthy volunteers participated in this study, 5 males and 3 females, with a mean age, body mass and height of 22.9 years, 68.5kg and 173.9cm respectively. Written informed consent was obtained from all volunteers and the institutional ethical committee approval was granted. All of the participants were fit and healthy without any history of injury, illness or pathology that could affect the cardiovascular, respiratory or locomotor systems.

A baseline (initial) assessment of each subject's gait was recorded using the Kistler Force Platform running Bioware Software, AVVS and the Polar HRM. All subjects wore flat shoes and shorts and were randomly assigned to either group A or group B. Below-knee walking casts were applied to their non-dominant leg by the same orthopaedic technician (JS) to achieve maximum functional and efficient use of the bandage materials. Two (2) volunteers (subject 6 and 7) wore casts on their right legs and the other 6 volunteers wore casts on their left legs. Each cast was worn for 3 days (72 hours) and the same gait recordings were made as in the baseline assessment.

Group A

Four (4) subjects were fitted with a BKWC made from rigid glass fibre bandage impregnated with polyurethane resin (Scotchcast, 3M Healthcare, Leicestershire, England). Two (2) rolls of 10cm wide bandage were used with minimal undercast padding to protect bony prominences. A Cellacast cast shoe was fitted to improve gait and to protect the heel and plantar surface of the cast (Lohmann GmbH, Germany).

Group B

Four (4) subjects were fitted with a BKWC made from Softcast and reinforced with a Scotchcast U-splint around the ankle to produce a Combicast (Fig. 3). Two (2) rolls (7.5 and 10cm wide) of Softcast reinforced with 7.5cm wide Scotchcast Longuette were used (3M Healthcare, Leicestershire, England). No undercast padding was used and the malleoli were protected with one layer of synthetic padding. This type of functional combination cast is designed to prevent subtalar joint movement by the use of U-splint reinforcing strip (Fig. 3) whilst allowing movement in the ankle and forefoot. All subjects in this group wore their own shoes.

Video and force platform recordings

Subjects were asked to walk at their self-selected comfortable speed along a 12 metre walkway in the gait laboratory. The Kistler force platform collected data at 1kHz. This process was repeated until each subject had achieved at lease 3 clean foot strikes on the force platform for each leg. The following recordings were

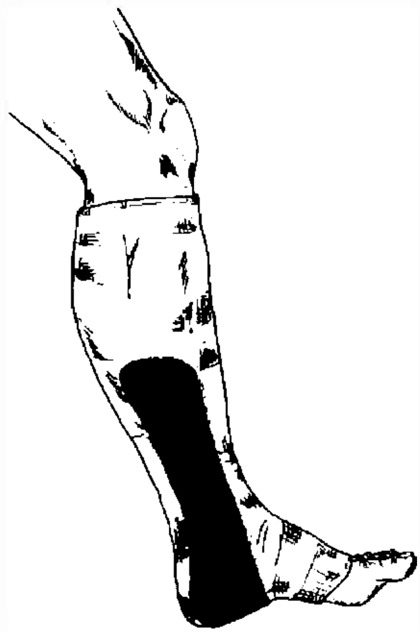


Fig. 3 shows the reinforcing U-strip in a below- knee Combicast. The flexible softcast glass fibre bandage is reinforced with the rigid Scotchcast glass fibre bandage.

made of each subject's gait before a BKWC was fitted (i.e. a baseline recording) and 3 days after it was fitted:

a) the peak vertical foot ground reaction forces (Fz_1 and Fz_3):
   Recorded from the force platform and acquired by Bioware:
b) temporal aspects recorded from videotape:
   gait cycle (stride) time
   stance/swing phase times (stance time also recorded from force platform)
   step/stride length
   walking speed, calculated from the product of step time and step length
c) gait symmetry indices:
   force platform
   temporal aspects (stance time)

PCI recording

Each subject was asked to avoid food, cigarettes and heavy physical exercise for 2 hours prior to the test and alcohol for 24 hours prior to testing. The test procedure required each subject to rest, seated quietly for 4 minutes, stand for 1 minute and then walk freely at their self-selected comfortable speed round a 20m long track (parallel sided with semicircular ends) for 4 minutes. Each subject walked for about 300 metres. The heart rate was recorded every 5 seconds throughout the 9 minute test period using a Polar Edge Heart Rate Monitor and the data transferred to a personal computer via the serial port interface for subsequent analysis. The average walking speed was obtained by counting the number of complete and partially complete circuits of the track and dividing by the 4 minute walking period. This procedure was carried out three times and the mean values of the resting heart rate, walking heart rate, and walking speed were calculated for each subject.

Statistical analysis

Statistical analysis was carried out using Microsoft Excel Spreadsheet (Microsoft Corporation, USA). A paired 't' test was used to determine differences in samples means for the gait cycle time, stance time, cadence, step and stride length, walking speed and PCI. The force platform data (Fz_1 and Fz_3), stance time, step and stride length were assessed using the Gait Symmetry Index (SI).

Discussion of results

This study has compared the gait of volunteers with a BKWC constructed from a rigid glass fibre casting bandage and wearing a cast shoe with a Combicast in which the volunteers wore their own footwear. The temporal and spatial factors of gait in 8 volunteers showed only small variations compared to normal gait (Table 1). The gait cycle time, stance phase time, step and stride length and walking speed were not significantly different ($p>0.05$) when a BKWC was applied.

A slightly higher walking speed with cast gait and a longer step length compared with normal gait were recorded for straight and level walking when recording the force platform data. These are well within the natural variability of gait parameters (White *et al.,* in press) but could be due to the fact that the volunteers walked faster when wearing a cast in order to establish a consistent rhythm to their gait and also because the recordings were made 72 hours after the baseline recordings. However, when the volunteers walked around the 20 metre track to record their PCI the walking speed was slightly

Table 1. Force platform/AVVS data
Group A – Rigid Cast

Subject	Mean gait cycle time (s)		Mean stance time (s)		Stance: Swing (%)		Cadence (step/min)		Stride length (m)		Walking speed (m/s)	
	Baseline	Cast	Baseline	Cast	Baseline	Cast	Baseline	Cast	Baseline	Cast	Baseline	Cast
3	1.09	1.09	0.69	0.69	63:37	63:37	110.3	109.7	1.32	1.32	1.19	1.21
4	0.98	0.99	0.61	0.61	62:38	62:38	122.7	121.7	1.31	1.44	1.33	1.46
5	1.09	1.10	0.71	0.69	65:35	63:37	110.1	109.3	1.50	1.50	1.37	1.36
8	1.08	0.98	0.68	0.61	63:37	62:38	112.9	112.2	1.36	1.27	1.26	1.29
Mean	1.06	1.04	0.67	0.65			113.5	115.7	1.36	1.38	1.29	1.33
s.d.	0.05	0.06	0.04	0.05			6.1	7.2	0.10	0.11	0.08	0.11

Group B – Combicast

Subject	Mean gait cycle time (s)		Mean stance time (s)		Stance: Swing (%)		Cadence (step/min)		Stride length (m)		Walking speed (m/s)	
	Baseline	Cast	Baseline	Cast	Baseline	Cast	Baseline	Cast	Baseline	Cast	Baseline	Cast
1	1.07	1.11	0.66	0.72	62:38	65:35	112.6	108.5	1.22	1.55	1.15	1.4
2	0.99	1.00	0.60	0.60	60:40	60:40	121.0	119.5	1.37	1.54	1.38	1.53
6	1.07	1.15	0.67	0.74	63:37	64:36	112.4	104.2	1.34	1.22	1.26	1.06
7	1.21	1.15	0.78	0.72	64:36	63:37	101.2	104.2	1.45	1.48	1.22	1.28
Mean	1.09	1.10	0.68	0.70			111.8	109.1	1.35	1.45	1.25	1.32
s.d.	0.09	0.07	0.08	0.06			8.12	7.25	0.10	0.15	0.10	0.20

slower when casts were worn than for their normal gait. This is probably due to much greater distance walked and having to walk around an elliptical track so that the speed would be modified when negotiating a change of direction.

The PCI increased by 9% when the volunteers wore a rigid cast and by 3.5% for the Combicast (Table 2). The PCI of walking in a rigid cast was found to be significantly greater than normal gait (p=0.022) but this was not the case for the Combicast (p=0.113). The restults of this study are similar to those reported by Ralston (1965) who found a 6% increase in the PCI of gait in 3 subjects with an immobilised ankle and by Fowler *et al.* (1993) who reported a 14.4% increase in PCI in 14 young adult male subjects. However, these results differ significantly from the study carried out by Hamzeh *et al.* (1998) who found that the PCI increased by 47.6% in 10 young adult subjects when fitted with standard plaster of Paris BKWCs. The PCI increased by over 400% when these same volunteers were fitted with a plantarflexed cast (115°).

Table 2. Physiological Cost Index (PCI) data
Group A – Rigid Cast

Subject	Average walking speed (m/min)		Increase in heart rate during walking (beats/min)		PCI (beats/m)	
	Baseline	Cast	Baseline	Cast	Baseline	Cast
3	72.5	75.0	13.0	15.8	0.179	0.209
4	67.8	66.7	21.1	22.0	0.311	0.33
5	73.8	66.7	28.9	30.5	0.392	0.457
8	80.8	78.5	30.6	32.1	0.383	0.408
Mean	73.73	71.73	23.40	25.10	0.316	0.351
s.d.	5.37	6.60	8.07	7.62	0.10	0.11
					p=0.022	

Group B – Combicast

Subject	Average walking speed (m/min)		Increase in heart rate during walking (beats/min)		PCI (beats/m)	
	Baseline	Cast	Baseline	Cast	Baseline	Cast
1	86.3	88.3	28.7	24.4	0.325	0.276
2	80.8	78.3	27.6	30.6	0.342	0.391
6	69.2	66.3	17.0	13.1	0.246	0.211
7	62.5	65.8	8.70	14.0	0.139	0.202
Mean	74.70	74.68	20.50	20.53	0.263	0.270
s.d.	10.81	10.77	9.47	8.45	0.09	0.09
					p=0.113	

Gait asymmetry increased with a cast gait compared to normal gait (Table 3). However, only the mean Symmetry Index (SI) of the first peak (Fz_1) in the force platform data was significantly greater than for normal gait (p>0.05). This was determined by comparing SI_{ul} of 5.7% for normal gait with the mean SI for the rigid bandage (10.3%) and for the Combicast (8.1%) (Table 4). Although the other parameters showed higher mean SI values than for normal gait they did not reach statistical significance (p<0.05). Volunteers also complained of discomfort when the rigid casts were used and discomfort was felt internally around the ankle and at the toe end of the casts due to the roughness of the bandage. No discomfort was reported in the Combicast. The rigid types of polyurethane casting materials are not forgiving and produce discomfort if not meticulously applied with appropriate padding and good technique. Softcast, however, is very forgiving and provides the necessary support when used in a Combicast.

In 1967 Sarmiento introduced functional below-knee walking casts which allowed early weight bearing and mobilisation of adjacent joints. The 1980s saw the introduction of a range of lightweight synthetic (polyurethane/glass fibre) bandages for conservative management of fractures and soft tissue injuries. They have much greater strength and durability than PoP and can be weight bearing within 30 minutes (Wytch *et al.*, 1987). The recent introduction of glass fibre materials with greater inherent flexibility allows combination casts to be fabricated with the appropriate strength and stiffness throughout the cast so that the optimum characteristics of a functional cast can be achieved. The benefits of combining materials minimises dysfunctional activity, allows better moulding of the casts to the limb and is more comfortable for the patient.

Conclusions

This study has shown that a very efficient gait can be achieved with modern synthetic bandages, if they are correctly applied. The temporal and spatial factors of cast gait were not statistically different from normal gait although cast gait was found to be slightly more asymmetrical (dominant versus non-dominant leg) and had a greater PCI. The Combicast has some advantages compared with the rigid glass

Table 3. Peak vertical ground reaction forces (Fz).

Subject	Cast type	Leg	Forces	Baseline (% bodyweight)		Cast (% bodyweight)	
				Mean	SD	Mean	SD
1	Combicast	Right	Fz_1	114.00	4.04	121.60	5.47
			Fz_3	111.80	2.05	111.00	5.70
		Left	Fz_1	116.00	5.57	115.20	5.63
			Fz_3	109.50	2.05	113.00	5.54
2	Combicast	Right	Fz_1	124.00	4.00	134.00	5.1
			Fz_3	112.20	3.11	113.90	4.24
		Left	Fz_1	124.50	4.43	120.20	2.92
			Fz_3	106.25	1.71	106.60	3.51
6	Combicast	Right	Fz_1	116.50	5.07	107.40	1.34
			Fz_3	113.25	1.50	108.60	0.89
		Left	Fz_1	119.67	3.06	119.40	4.28
			Fz_3	110.33	2.08	104.60	2.61
7	Combicast	Right	Fz_1	104.20	5.22	106.50	2.08
			Fz_3	106.40	5.73	103.50	3.11
		Left	Fz_1	104.25	3.30	108.75	7.37
			Fz_3	108.25	3.40	111.50	1.91
3	Scotchcast	Right	Fz_1	103.39	4.75	115.33	4.16
			Fz_3	116.75	0.96	120.33	2.08
		Left	Fz_1	103.18	2.45	102.60	2.70
			Fz_3	113.60	1.67	108.40	2.07
4	Scotchcast	Right	Fz_1	112.40	3.21	123.40	2.07
			Fz_3	107.80	3.03	103.80	1.79
		Left	Fz_1	115.00	5.21	109.40	3.05
			Fz_3	108.33	0.58	104.00	2.12
5	Scotchcast	Right	Fz_1	115.40	4.04	125.80	2.39
			Fz_3	111.00	3.00	113.40	2.61
		Left	Fz_1	110.00	3.94	107.00	4.00
			Fz_3	111.00	3.00	106.00	2.04
8	Scotchcast	Right	Fz_1	107.00	2.92	116.60	7.02
			Fz_3	101.40	1.67	101.80	4.38
		Left	Fz_1	112.67	4.93	116.20	3.11
			Fz_3	106.67	1.53	104.60	1.95

A BKWC was worn on the right leg in subjects 6 and 7 and on the left leg in the other subjects.

fibre bandage as normal footwear can be worn, the casts are more comfortable and they could be removed with shears. This obviates the need for a power saw.

Although the concepts of functional immobilisation are well established they are not widely practised in the conservative management of musculo-skeletal injuries. The

Table 4. Gait Symmetry Indices: dominant vs non-dominant leg.

Baseline	Mean SI (%)	SD (%)	SI_{ul} (±) (%)
Fz_1	-1.0	2.4	5.7
Fz_3	-0.7	3.0	7.1
Stance time	1.0	3.2	7.6
Step length	1.5	3.3	7.8
Stride length	1.2	3.7	8.7
Soft cast			
Fz_1	8.1	5.5	Greater
Fz_3	3.0	4.3	OK
Stance time	4.5	3.3	OK
Step length	3.2	4.0	OK
Stride length	1.2	2.6	OK
Rigid cast			
Fz_1	10.3	6.9	Greater
Fz_3	5.1	4.5	OK
Stance time	6.5	2.8	OK
Step length	1.3	4.2	OK
Stride length	0.9	2.6	OK

use of combination casts is likely to encourage functional immobilisation as an efficient and comfortable gait can be produced. This type of cast provides an advance in the treatment of fractures and soft tissue injuries.

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