The Egyptian Journal of Medical Human Genetics (2013) **14**, 183–188

Ain Shams University

The Egyptian Journal of Medical Human Genetics

www.ejmhg.eg.net
www.sciencedirect.com

ORIGINAL ARTICLE

Efficacy of adhesive taping in controlling genu recurvatum in diplegic children: A pilot study

Asmaa M. Ghalwash, Shorouk A.W. El-Shennawy *, Manal S. Abd-Elwahab

Pediatrics Department, Faculty of Physical Therapy, Cairo University, Egypt

Received 17 October 2012; accepted 5 November 2012
Available online 31 December 2012

KEYWORDS
Adhesive taping;
Cerebral palsy;
Spastic diplegia;
Genu recurvatum;
Auto CAD;
Screen protractor

Abstract Adhesive taping has been commonly used to improve the performance through supporting joint structure and reducing pain. Restoring knee alignment in diplegic children is critical in an effective treatment program. The purpose of this article is to investigate whether adhesive taping is effective in controlling genu recurvatum in diplegic cerebral palsy children. Fourteen children with diplegic cerebral palsy (8 boys and 6 girls with a mean age of 6.22 years), participated in a 12-week program. Children were assigned randomly to one of two groups: therapeutic taping + physical therapy or knee cage + physical therapy. Therapeutic taping was applied for periods of up to 60 h over knee. The effects were assessed with the Gross Motor Function Measure (GMFM-88), Auto CAD, Screen protractor at baseline and 12 weeks after treatment. The primary outcome measure was knee angulations, using Auto CAD and screen protractor software. The Gross Motor Function Measure-88 (GMFM-88) standing and walking subsections were the secondary outcome measures. No significant differences were found between groups over time. Adhesive taping does not evoke a positive change in controlling genu recurvatum in children with diplegic cerebral palsy.

1. Introduction

Genu recurvatum is a deformity in the tibiofemoral joint in which the range of motion occurs beyond neutral or 0° of extension. It is a commonly acquired deformity in children with ligamentous laxity, musculoskeletal and upper motor neuron pathologies. Because genu recurvatum has the potential to become a chronic deteriorating problem, adequate management during rehabilitation is essential [1].

Genu-recurvatum can be classified into dynamic (functional) and structural knee genu recurvatum. Dynamic knee recurvatum is defined as hyperextension of the knee during the stance period of the gait cycle and this impairment is neurological based. This disorder is typically ascribed to a combination of quadriceps weakness, ankle planter flexor spasticity, heel cord contracture, quadriceps spasticity, and/or gastrosoleus weakness, and is seen in patients with cerebral palsy. The structural genu recurvatum can be congenital due to abnormal intra-uterine posture and spontaneous recovery usually occurs, or can be acquired [2].

Most children with spastic diplegia easily develop genu recurvatum due to excessive activity of the calf muscles in

* Corresponding author. Fax: +20 237617692.
E-mail address: Shoroukelshennawy@gmail.com (Sh.A.W. El-Shennawy).
Peer review under responsibility of Ain Shams University.

Production and hosting by Elsevier

1110-8630 © 2012 Ain Shams University. Production and hosting by Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.ejmhg.2012.11.001

response to the increasing dorsiflexion moment about the ankle produced by the foot–floor reaction force arrested the forward motion of the tibia. Recurvatum is produced when the femur continued to move forward over the stationary tibia which produces an extension moment at the knee [3].

In rehabilitation programs, it is a challenge to find a way to stimulate the sensorimotor system toward regaining normal voluntary movement and limb functional use. The goal of most therapy programs is to maintain the affected extremity in the best possible aligned position to avoid overstretched soft tissue, edema, and pain. Through the exercise program and use of weight-bearing techniques, the therapist attempts to maintain and improve trunk and limb alignment to allow the functional use of the extremity [4].

Adhesive tape is the tape that has elastic properties, this property allows the tape to work with the soft tissue of the body versus restricting it, and also makes the tape a good modality for the treatment of various conditions in pediatrics such as muscle tightness, muscle weakness, lymph edema and chronic swelling [5].

The taping provides protection and support for a joint while permitting optimal functional movement. The traction on the skin or the pressure of the tape provides cutaneous sensory cues, thus providing additional proprioceptive input to the central nervous system. The effect of tape can only partially be explained by increased mechanical stability, however, that taping may have some proprioceptive influences [6].

Swedish knee cage; a knee orthosis with an extension stop and free knee flexion is effective in controlling knee hyperextension owing to increased extensor tone during stance. Such orthosis is of benefit for gait training purpose during the rehabilitation process [7–9].This orthosis can control varus/valgus and rotatory instabilities that may accompany recurvatum [10].

2. Subjects and methods

2.1. Participants

Volunteers were recruited using advertisements placed in local therapy clinics. A research team member screened volunteers using the following inclusion criteria : (1) medical diagnosis of cerebral palsy (CP), spastic diplegia; with a degree of spasticity of lower limb muscles ranged from grade 1 to grade 2 according to the Modified Ashworth Scale (MAS); (2) boys or girls between the ages of 5–7 years; (3) able to walk without physical assistance; (4) demonstrated recurvatum up on observational standing posture; (5) classified with a maximum of level III on the Gross Motor Function Classification System for Cerebral Palsy (GMFCS); (6) not participated in any previous trials with adhesive tape to lower limb musculature; and (7) can understand and follow the verbal commands. Children were excluded if they had (1) surgical intervention to correct lower-extremity orthopedic abnormalities; (2) any orthopedic or neurologic condition identified by the physician's referral that was contraindicative of positioning the child in a vertical standing position; (3) demonstrated allergic reactions to the adhesive tape or any other materials used in this study; (4) severe muscle contracture; (5) visual or auditory disorders.

Using the above inclusion/exclusion criteria, a total of 15 volunteers were screened, one was excluded because of the inability to make all sessions/transportation issues. Thus, 14 children were found eligible and their caregiver agreed to participate (8 boys and 6 girls).

2.2. Instruments

2.2.1. Auto CAD

Auto CAD® 2008 software (Autodesk Inc., San Rafael, CA, USA) analysis was carried out by a specialist engineering with 3 years of experience in using the measures. The approach selected for measuring sagittal plane limb alignment uses five bone landmarks of the femur and tibia [11]. Midstance sub phase of gait cycle was recorded from the child sagittal view. Knee angulation was measured as the angle formed by the intersection of the femoral axes and tibial axes. The femoral axis was formed by a line from the center of the greater trochanter to the mid-lateral border of the knee, while tibial axis was produced by a line from mid-lateral border of the knee to the center of lateral malleoli.

2.3. Screen protractor (Version 4)

Screen protractor allows easy and quick measurement of any angle on the screen to the nearest degree or radian (http://www.iconico.com/protractor/). The recorded midstance subphase picture was also analyzed using screen protractor. For measuring knee angle; the fulcrum of protractor was positioned over the middle of lateral knee articulation marker, and the protractor arms were then positioned to bisect the adjacent joint markers i.e. middle of both greater trochanter and lateral malleolus.

2.4. Gross Motor Function Measure (GMFM-88)

The Gross Motor Function Measure (GMFM) is a criterion-referenced observational measure that was developed and validated to assess children with cerebral palsy [12]. The reliability of scores obtained with the 88-item GMFM was sufficiently high (intraclass correlation coefficient [ICC] 5.90). The 88 items of the GMFM are measured by observation of the child and scored on a 4-point ordinal scale (05 does not initiate, 15 initiates 10% of activity, 25 partially completes 10–100% of activity, 35 completes activity). The items are weighted equally and grouped into 5 dimensions: (1) lying and rolling (17 items), (2) sitting (20 items), (3) crawling and kneeling (14 items), (4) standing (13 items), and (5) walking, running, and jumping (24 items) [13]. The last two dimensions were tested in this study prior to initiating intervention and immediately at the end of intervention. Scores for each dimension were expressed as percentage of the maximum score for that dimension. Scoring was carried out by a research physiotherapist trained in the use of these measures.

2.5. Testing, randomization, and interventions

Before screening, children caregiver who had accepted to participate in the study signed an informed, written consent that was obtained in accordance with the ethical standards of the Helsinki declaration of 1975, as revised in 2000. The degree of knee angulations for all children was evaluated using both Auto CAD analysis and screen protractor whereas their motor abilities were assisted using GMFM-88. By the end of pretesting session, children were randomly assigned by a sealed envelope into one of two groups: (1) the study group (n = 7; taping intervention and physical therapy program [PT]); and (2) the control group (n = 7; posterior knee cage and PT). The randomization was conducted by physiotherapist who was not involved in delivering the interventions. All children received therapy in the same environment in the same fashion and from the same therapists.

2.6. Taping group

To test the hypothesis that the combination of physical practice while wearing adhesive tape would be more effective than physical practice while wearing knee cage, spastic diplegia children were assigned randomly to 1 of 2 conditions; taping group (n = 7) and cage group (n = 7). All children received therapy in 60-min therapy sessions for 3 days a week for 12 weeks. 3NS® TEX Tape was used in this research. The tape is made of 100% cotton. It is free of latex and it was applied to the backing paper with 10% available stretch. Its degree of stretch is 30–40% from the resting length with 40% being the maximal stretch of the tape; this stretch was along longitudinal axis only. The thickness and weight of tape are approximately those of skin, also the elastic property of the tape is similar to the skin as well. Therefore most patients easily tolerate the tape. It allows free movement and do not restrict movement. Taping materials were applied as follows: The degree of hyperextension that required eliciting knee discomfort was determined. The skin was prepared by applying the milk of Magnesia with 2×2 gauze pads over back of the knee. Knee hyperextension taping begin by placing a lift under the heel to flex the knee. The back of the knee was protected by tape then proximal and distal anchor strips were placed around the thigh and calf respectively. Elastic tape was used to apply vertical strip. Then two strips were overlapped, creating an x shape over the back of the knee. The procedures were completed by enclosing the knee in an elastic wrap [5].

2.7. Physical therapy program

Each child of both groups participated in a physical therapy program, attending three 1-h sessions per week for 12 weeks. The program used a combination of open- and closed-chain exercises for maximum transfer to both the stance and swing phases of gait, and these exercises were designed to restore normal flexibility and strength for the hamstring as well as quadriceps muscles including; progressive resistance exercise program using free weights or pulley system (suspension), that targeted the hamstring and quadriceps muscles bilaterally.

2.8. Post intervention test

After 12 weeks, all children were again administered knee angulation measurements and GMFM by the same examiner who pretested them.

2.9. Statistical analysis

Results are expressed as mean ± standard deviation (SD) or number (%). Comparison between different variables in the two groups was performed using Mann–Whitney U test while comparison between variables within the same group was performed using Wilcoxon test. Comparison between categorical data was performed using Chi square test. SPSS computer program (version 12 windows) was used for data analysis. P Value less or equal to 0.05 was considered significant.

3. Results

The children characteristics are reported in Table 1. The two groups were compared on demographic variables and baseline scores. Due to our small number, the distributional assumptions that underlie the t test could not be satisfied. Thus, Wilcoxon tests were applied and revealed non significant differences (P = 0.805) between the groups in mean age of diplegic children. Groups also did not differ on sex nominal variable before intervention. Five out of the seven children in the taping group were boys, as did three in the cage group (P = 0.280). The comparisons of GMFCS and Modified Ashwar Score between the two groups at pretesting also did not reveal significant differences P = 0.515 and 0.069 respectively.

In children of taping group after 3 months of treatment the values become closer to the pretreatment values (Rt CAD pre-

Table 1 Preintervention demographics and scores, by group.

	Tape mean (SD)	Cage mean (SD)	P value
Age (yrs)	6.19 (0.59)	6.26 (0.28)	0.805
Gender (F/M)	5/2 (71.4%/28.6%)	3/4 (42.9%/57.1%)	0.280
GMFCS level (II/III)	6/1 (85.7%/14.3%)	5/2 (71.4%/28.6%)	0.515
Modified Ashwar (1/1 + /2)	3/2/2 (42.9%/28.6%/28.6%)	0/6/1 (0%/85.7%/14.3%)	0.069
Mean CAD angle			
Rt	192 (3.92)	191.86 (3.02)	0.902
LT	194 (4.4)	194.86 (6.12)	1
Mean screen angle			
Rt	118.71 (2.56)	192 (3.1)	0.805
Lt	116.57 (5.62)	195.17 (5.95)	1
Mean GMFM			
Standing	31.43 (2.7)	31 (2.65)	0.710
Walking	38.14 (11.17)	36.14 (7.38)	0.710

Data are expressed as mean (SD) or number (%).
Standard deviation (SD), Probability (P), Years (yrs), Female/Male (F/M), Gross Motor Function Classification System (GMFCS).

Table 2 Knee angulation measurement of Auto CAD and screen protractor before and after intervention.

	Auto CAD				Protractor			
	Taping group		Cage group		Taping group		Cage group	
	Rt mean (SD)	Lt mean (SD)	Rt mean (SD)	Lt mean (SD)	Rt mean (SD)	Lt mean (SD)	Rt mean (SD)	Lt mean (SD)
Pre	192 (3.92)	194 (4.4)	191.86 (3.02)	194.86 (6.12)	192.31 (3.88)	194.32 (4.34)	192 (3.1)	195.17 (5.95)
Post	191.86 (4.3)	193.57 (5.06)	188.86 (3.02)	192 (6.3)	191.93 (4.02)	193.60 (5.07)	189.2 (3.02)	192.06 (6.35)
P value	0.783	0.257	0.017*	0.017*	0.310	0.063	0.018*	0.018*

Significant change scores are denoted by "*".
Standard deviation (SD), Probability (*P*), Pre treatment (Pre), Post treatment (Post).

Table 3 Auto CAD and protractor post treatment between – Group Difference.

	CAD		Protractor	
	Rt mean (SD)	Lt mean (SD)	Rt mean (SD)	Lt mean (SD)
Taping group	191.86 (4.3)	193.57 (5.06)	191.93 (4.02)	193.6 (5.07)
Cage group	188.86 (3.02)	192 (6.3)	189.2 (3.02)	192.06 (6.35)
P value	0.209	0.318	0.209	0.383

Standard deviation (SD), Probability (*P*).

Table 4 GMFM-88 for standing and walking dimension scores.

	Taping group				Cage group			
	Standing		Walking		Standing		Walking	
	Score mean (SD)	% Mean (SD)	Score mean (SD)	% Mean (SD)	Score mean (SD)	% Mean (SD)	Score mean (SD)	% Mean (SD)
Pre	31.43 (2.70)	80.58 (6.92)	38.14 (11.17)	52.97 (15.52)	31 (2.65)	79.48 (6.78)	36.14 (7.38)	50.19 (10.25)
Post	34 (2.52)	87.17 (6.46)	40.43 (10.85)	56.15 (15.06)	33.57 3.21)	86.05 (8.21)	39.43 (8.4)	54.76 (11.67)
P value	0.011*	0.017*	0.017*	0.018*	0.027*	0.028*	0.043*	0.043*

Significant change scores are denoted by "*".
Standard deviation (SD), Probability (*P*).

treatment 192 ± 3.92; post treatment 191.86 ± 4.3; $P = 0.783$, Lt CAD pretreatment 194 ± 4.4; post treatment 193.57 ± 5.06; $P = 0.257$). All the children in cage group showed a reduction of knee angulation measurement of both lower limbs using CAD ($P = 0.017$) as well as protractor ($P = 0.018$) Table 2.

Furthermore, with the Mann–Whitney U test, knee angulation difference of the two groups post treatment (Table 3) was statistically insignificant ; for both Auto CAD measurement (Rt taping group 191.86 ± 4.3; cage group 188.86 ± 3.02; $P = 0.209$, Lt taping group 193.57 ± 5.06; cage group 192 ± 6.3; $P = 0.318$) as well as protractor measurement (Rt taping group 191.93 ± 4.02; cage group 189.2 ± 3.02; $P = 0.209$, Lt taping group 193.6 ± 5.07; cage group 192.06 ± 6.35; $P = 0.383$).

For the GMFM paired Wilcoxon analysis showed a statistically significant improvement in both groups at post treatment with respect to the pretreatment condition in both standing and walking dimensions (score and percentage) (Table 4).

With regard to between – Group Difference (Table 5) the Mann–Whitney U test; revealed no differences in both groups regarding standing (taping group GMFM score: 34 ± 2.52, cage group 33.57 ± 3.21; $P = 0.902$) and walking scores (taping group GMFM score: 40.43 ± 10.85, cage group 39.43 ± 8.4; $P = 0.902$).

4. Discussion

This study is the first to investigate the effect of adhesive taping in controlling genu recurvatum in diplegia children. The intervention used in this study was designed to be used throughout the day and, thus, could be incorporated into many functional activities that the child encounters in everyday life.

The following discussion will review the findings, limitations and conclusions of this investigation. Genu recurvatum has been described as a chronic, perpetuating problem which tends to begin with a disorder of a small magnitude that exacerbates over time. Despite the finding that 40–68% of patients with neurological deficits, suffer from knee hyperextension, little attempt has been made to evaluate the outcome of physical therapy treatment or to compare the effectiveness of different management approaches [14].

Choosing midstance sub phase of gait cycle to measure knee angulations agrees with Perry [15] who reported that hyperextension occurs when the knee has the mobility to

Table 5 Post treatment between – Group Difference for standing and walking dimension scores of GMFM-88.

	Standing		Walking	
	Score mean (SD)	% Mean (SD)	Score mean (SD)	% Mean (SD)
Taping group	34 (2.52)	87.17 (6.46)	40.43 (10.85)	56.15 (15.06)
Cage group	33.57 (3.21)	86.05 (8.21)	39.43 (8.4)	54.76 (11.67)
P value	0.902	0.710	0.902	0.902

Standard deviation (SD), Probability (*P*).

angulate backward (recurvatum) occurring in any of the weight-bearing phases; as extensor thrust often is the first reaction to limb loading. So hyperextension is a later development either as a reaction to the added stimulus of single limb support or advancement of the body (and thigh) over a stationary tibia. He concluded that hyperextension can develop in either mid stance or terminal stance, and this posture, then, is continued into pre-swing.

Previous researches [16–19] have demonstrated the usefulness of the GMFM-88 tool for assessing functional outcomes of intervention studies, including PT, selective dorsal root rhizotomies, and therapeutic electrical stimulation.

Unfortunately, the knee angulation measurement; using both Auto CAD and screen protractor in addition to motor outcome measurement using GMFM-88 failed to detect any significant changes post treatment between-groups difference that could be attributed to small sample size as after applying the study criteria, 15 subjects were screened for this study, with only one excluded and the remaining 14 subjects were included. Also it could be attributed to inability to quantitatively determine the degree of genu recurvatum using for example X-ray before including children in the study as the authors only depend on appearance of genu recurvatum on observational standing posture for their inclusion. Thus, non significant change between groups post treatment may have been related to the lack of accurate measurement of severity of genu recurvatum of the children studied at their entry level.

In addition the 12-week taping timeframe in this study may have influenced the outcomes [20,21]. Blair et al. [22] intervened for a 16-week period with reported functional change. The four-week time differential between the present study and the study reported by Blair et al. [22] might also have affected the long-term functional outcomes of this investigation. In other words, the children were simply unable to demonstrate a functional change in such a short period of time. This finding is consistent with Knox [23], who studied a similar population, but for a four-week period of time.

In the current study the results revealed that the patients had achieved a significant reduction in recurvatum of the knee with the application of knee cage. This improvement could be due to the effective re-educating knee control gained through the application of knee cage. By using the appliance, the lower limb was enabled to transmit weight efficiently, which allows the patient to stand and bear weight confidently [24].

Non significant improvement in knee angulation measurement with both; Auto CAD and protractor of the taping group could be attributed to limited ability of the tape to overcome the child musculoskeletal problems. Such musculoskeletal problems present a major constraint to normal posture and movement control in diplegia children secondary to spasticity or soft tissue abnormalities which can restrict the movement and so disturb the postural alignment. This agreed with Shumway-Cook [25], who stated that, spastic diplegic patients are likely to have neuromuscular impairments which interfere with the development of proper posture control in addition to changes in the structure and function of the skeletal muscles particularly in the lower extremities.

Improvement in post treatment mean value of GMFM with respect to pretreatment value of the taping group could be attributed to traction on the skin or the pressure of the tape which provides cutaneous sensory cues, thus providing additional proprioceptive input to the central nervous system [6]. Significant improvement in standing and walking ability of taping group could also be due to joint protection and support provided by the tape while permitting optimal functional movement.

5. Conclusion

The predominance of statistical evidence presented in this study suggested that therapeutic taping was an ineffective means for addressing genu recurvatum in children with diplegia.

Funding resources

None.

Conflict of interest

None.

Acknowledgment

The authors gratefully appreciate Dr. Tarek M. Diab, Assistant Professor in Theodor Bilharz Research Institute- Egypt, for his statistical assistance. The authors wish to acknowledge the contribution of Eng. Hatem Hassan in (Sabbour Associates Engineers- Egypt) for analyzing Auto ACD program.

References

[1] Fish DJ, Kosta CS. Genu recurvatum: identification of three distinct mechanical profile. JPO 1998;10(2):26–32.
[2] Kerrigan DC, Deming LC, Holden MK. Knee recurvatum in gait: a study of associated knee biomechanics. Arch Phys Med Rehab 1996;77(7):645–50.
[3] Simon SR, Deutsch SD, Nuzzo RM, Mansour MJ, Jackson JL, Koskinen M, et al. Genu recurvatum in spastic cerebral palsy. Report on findings by gait analysis. J Bone Joint Surg Am 1978;60(7):882–94.

[4] Jaraczewska E, Long C. Kinesio® taping in stroke: improving functional use of the upper extremity in hemiplegia. Top Stroke Rehabil 2006;13(3):31–42.

[5] Kase K, Martin M, Yasukawa A. Kinesio taping® in pediatrics, fundamentals and whole body taping infant to adolescent full color step by step 2006:17–9.

[6] Perrin D. Athletic taping and bracing. In: Human Kinetics, 2nd ed. Champaign, IL: Human Kinetics; 2005. p. 56.

[7] Kogler GF. Orthotic management. In: Gelber DA, Jefferym DR, editors. Clinical evaluation and management of spasticity. New Jersey: Humana Press; 2002. p. 67–92.

[8] Koczur EL, Strine CE, Peischl D, Lytton R, Rahman T, Alexander MA. Orthotic and assistive devices. In: Alexander MA, Matthews DJ, editors. Pediatric rehabilitation: principles and practice. New York, NY: Demos Medical Publishing; 2010. p. 103–227.

[9] Ackman JD, Russman BS, Thomas SS, Buckon CE, Sussman MD, Masso P, et al. Comparing botulinum toxin A with casting for treatment of dynamic equinus in children with cerebral palsy. Dev Med Child Neurol 2005;47:620–7.

[10] Seymour R. Orthoses for orthopedic conditions. Prosthetic and orthotics, lower limb and spinal. London: Lippincott Williams & Wilkins; 2002, p. 337–366.

[11] Bergen D. Stages of play development; play as a medium for learning and development. Portsmouth, NH: Heinemann; 2000.

[12] Russell DJ, Rosenbaum PL, Cadman DT, et al. The Gross Motor Function Measure: a means to evaluate the effects of physical therapy. Dev Med Child Neurol 1989;31:341–52.

[13] Russell DJ, Rosenbaum PL, Gowland C, et al. Manual for the Gross Motor Function Measure. 2nd ed. 1993. (Available from CanChild Centre for Childhood Disability Research, Room 408, Institute for Applied Health Sciences, McMaster University, 1400 Main St W, Hamilton, Ontario, Canada L8S 1C7.).

[14] Morris ME, Matyas TA, Bach TM, Goldie PA. Electrogoniometric feedback: its effect on genu recurvatum in stroke. Arch Phys Med Rehabil 1992;73(12):1147–54.

[15] Perry J. Gait analysis: normal and pathological function. SLACK Incorporated 1992;223:254.

[16] Hays RM, McLaughlin JF, Bjornson KF, et al. Electrophysiological monitoring during selective dorsal rhizotomy, and spasticity and GMFM performance. Dev Med Child Neurol 1998;40:233–8, R.

[17] McLaughlin JF, Bjornson KF, Astley SJ, et al. Selective dorsal rhizotomy: efficacy an safety in an investigator-masked randomized clinical trial. Dev Med Child Neurol 1998;40:220–32.

[18] Steinbok P, Reiner AM, Beauchamp R, et al. A randomized clinical trial to compare selective posterior rhizotomy with physiotherapy alone in children with spastic diplegic cerebral palsy. Dev Med Child Neurol 1997;39:178–84.

[19] Wright V, Sheil EM, Drake JM, et al. Evaluation of selective dorsal rhizotomy for the reduction of spasticity in cerebral palsy: a randomized controlled trial. Dev Med child Neurol 1998;40:239–47.

[20] Nicholson JH, Morton RE, Attfield S, et al. Assessment of upper-limb function and movement in children with cerebral palsy wearing lycra garments. Dev Med Child Neurol 2001;43: 384–91.

[21] Rennie DJ, Attfield SF, Morton RE, et al. An evaluation of lycra garments in the lower limb using 3-D gait analysis and functional assessment (PEDI). Gait Posture 2000;12:1–6.

[22] Blair E, Ballantyne J, Horsman S, et al. A study of a dynamic proximal stability splint in the management of children with cerebral palsy. Dev Med Child Neurol 1995;37:544–54.

[23] Knox V. The use of lycra garments in children with cerebral palsy: a report of a descriptive clinical trial. Br J Occup Ther 2003;68:71–7.

[24] Farncombe PM. The Swedish knee cage. Management of the hyperextended hemiplegic knee. Physiotherapy 1980;66(1):33–4.

[25] Shumway-Cook A, Wollacott M. Motor control theory & practical application. 2nd ed. London: Lippincott Williams & Wilkins; 2001, p. 223–261.