Gait & Posture 68 (2019) 388–396

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

Full length article

Effect of Kinesio taping on Y-balance test performance and the associated leg muscle activation patterns in children with developmental coordination disorder: A randomized controlled trial

Timothy T.T. Yam[a], Peggy P.L. Or[b], Ada W.W. Ma[b], Shirley S.M. Fong[a,b,*], Man Sang Wong[c]

[a] School of Public Health, LKS Faculty of Medicine, The University of Hong Kong, Hong Kong
[b] Department of Health and Physical Education, Faculty of Liberal Arts and Social Sciences, The Education University of Hong Kong, Hong Kong
[c] Department of Biomedical Engineering, Faculty of Engineering, The Hong Kong Polytechnic University, Hong Kong

ARTICLE INFO

Keywords:
Developmental coordination disorder
Postural stability
Electromyography
Kinesiology tape
Dynamic balance

ABSTRACT

Background: Children with developmental coordination disorder (DCD) have leg muscular deficits which negatively affects their dynamic postural stability. Kinesio tape (KT) could enhance muscle activation, postural control and functional activities in healthy individuals. Therefore, we hypothesized that the usage of KT may address the postural instability problem of children with DCD.
Research question: To investigate the immediate effect of KT on dynamic postural stability and the associated lower limb muscle activity in children with DCD.
Methods: Forty-nine children with DCD were recruited where twenty-five children were randomly assigned to the KT group (mean age = 8.18 ± 1.16 years) and twenty-four to the control group (mean age = 8.06 ± 0.93 years). KT group received KT application to the rectus femoris and gastrocnemius muscles whereas the control group received no intervention. Measurements were taken before and after the application of KT. Dynamic balance performance was measured using a lower quartile Y-balance test (YBT-LQ). Leg muscle peak activation and time-to-peak muscle activation of the dominant lower limb during YBT-LQ were measured by surface electromyography.
Results: YBT-LQ composite score increased by 6.3% in the KT group at posttest (95% CI: -7.308, -2.480). In addition, a higher rectus femoris peak activation was illustrated for YBT-LQ anterior (32.5%; 95% CI: -48.619, -16.395) and posteromedial (24.6%; 95% CI: -42.631, -6.591) reach directions from pretest values in the KT group. Moreover, KT group exhibited a 38% (95% CI: 0.015, 2.983) longer gastrocnemius medialis time-to-peak duration for YBT-LQ posteromedial reach direction when compared to the control group.
Significance: KT revealed an immediate beneficial effect on YBT-LQ performance. Application of KT also increased rectus femoris peak activation and lengthened the muscle time-to-peak duration for specific reach directions. Incorporating KT as an adjunct with dynamic balance training programme could be beneficial for children with DCD.

1. Introduction

Developmental coordination disorder (DCD) is a common neuromotor condition, affecting around 6% of school-age children [1]. Children with DCD demonstrate poor motor control with decreased lower limb muscle power and electromyography (EMG) activity during many daily activities [2,3]. In particular, they exhibit longer hamstring and gastrocnemius muscle activation onset latencies during unexpected perturbations in standing *which accounts to around 20% of balance performance* [4]. Furthermore, children with DCD have a less competent dynamic balance control measured by the Lower Quarter Y-balance Test (YBT-LQ) which is an equipment to assess dynamic balance performance [5]. The motor and balance deficits negatively influence normal daily activities and may persist to adulthood [6] which is of great concern for parents, clinicians and teachers.

Dynamic postural stability involves controlling the body's center of mass within the base of support by generating appropriate feedback and feedforward responses [7]. Feedforward control (i.e., *anticipatory postural adjustment)* is fundamental and generally developed in children as early as age of 6 to reliably control postures and navigate accurately

* Corresponding author at: School of Public Health, The University of Hong Kong, Pokfulam, Hong Kong.
E-mail address: smfong@hku.hk (S.S.M. Fong).

https://doi.org/10.1016/j.gaitpost.2018.12.025
Received 7 September 2018; Received in revised form 15 December 2018; Accepted 17 December 2018
0966-6362/

throughout movements [8]. However, children with DCD likely have an underdeveloped and heterogenous feedforward response for dynamic postural adjustments. The dissimilar postural muscle response is the primary cause of atypical feedforward control in children with DCD [5]. Therefore, exploring interventions to improve feedforward postural control and dynamic postural stability is essential.

Kinesio tape (KT) is commonly used in rehabilitation which claims to normalize muscle *tension* [9]. It is because KT stimulates the cutaneous receptors which changes the muscle spindle sensitivity [10] and EMG activity [11]. Previous studies have reported that patients with impaired postural stability, such as those with chronic ankle instability and patellofemoral pain syndrome, also benefited from KT by improving their neuromuscular control and feedback/ feedforward balance performance measured by the Sensory Organization Test and Kinesthetic Ability Trainer [12,13]. Therefore, we postulated that KT may also induce positive changes on muscle activity efficiencies and dynamic balance performance in children with DCD. Accordingly, the aim of this study was to investigate the immediate effect of KT on lower limb muscle activity during dynamic balance performance in these children.

2. Methods

2.1. Study design

This randomized controlled study used a parallel-group design. Ethical clearance was obtained from the Human Research Ethics Committee of the University of Hong Kong with the trial registered under the ClinicalTrials.gov (NCT02945124) and was conducted in accordance with the Declaration of Helsinki (2013). Written, informed consents were obtained from participants and parents before the study was administered by two physiotherapists which took place at the Physical Activity Laboratory at the University of Hong Kong.

2.2. Participants

Participants aged 6 to 9 years were recruited from local primary schools and community through invitation letters, advertisements and personal invitations. The two-step method [5] was used to determine children with DCD by using Movement Assessment Battery for Children, 2nd edition [14] and information provided by parents/teachers.

Exclusion criteria consisted of (i) history of serious lower limb injuries (i.e., fractures) which may limit participant's ability to perform large lower limb range of motion movements; (ii) receiving rehabilitative or any related treatments in the recent 2 months; (iii) excessive disruptive behaviour; (iv) inability to follow instructions; (v) tape allergy; (vi) open/chronic wound at the lower limbs; (vii) previous KT experience; or (viii) any disorder (e.g., cardiopulmonary diseases and musculoskeletal problems) that may interfere with children's locomotor or exercise ability.

2.3. Screening, randomization and allocation concealment

An independent individual randomly allocated the eligible participants to either a KT or a control group (Fig. 1). Block randomization (blocks of four) was used to ensure each group had equal number of participants. Allocation concealment was ensured with sealed opaque envelopes used.

2.4. Taping intervention

The KT group received KT application to the bilateral rectus femoris and gastrocnemius muscles in accordance to the KT application guidelines for paediatric population [9] whereas the control group received no intervention. KT (Kinesio Tex Gold©, Kinesio Holding Corporation, Albuquerque, NM, USA) was applied on top of any electrodes to the participants in a seated position by an experienced physiotherapist. KT application took around 20 min for each participant in the KT group whereas control group participants rest in a seated position for that duration.

To maintain the consistency of the KT tension applied to the muscles, the leg length was considered when calculating the KT length with the following equation [5]:

$$\textit{Actual length of tape to cut } (cm) = \left[\left(\frac{x-4}{1.5}\right)+4\right]\times 1.10$$

where x is the measured length between the origin and insertion sites. The anchor length was set at 4 cm (2 cm each for proximal and distal sites).

For the rectus femoris muscle, a Y-shaped KT was applied in a seated position with knee supported in 60° flexion. Proximal and distal end (tension free) were located 5 cm below the anterior superior iliac spine and below the patella region at the level of tibial tuberosity, respectively. A 50% tension was present at the middle portion and the medial and lateral tails arising from the tape junction (Fig. 2) [9].

For the gastrocnemius muscle, two I-shaped KT was applied in the seated position with knee in slight flexion and ankle in full dorsiflexion. Proximal and distal end (tension free) were located at the posterolateral aspect of knee just below the knee joint line and at the base of calcaneus, respectively. A 50% tension was present at the middle portion along the medial and lateral heads of gastrocnemius muscle (Fig. 3) [9].

2.5. Test procedures

2.5.1. Demographics

The parents first provided participant information regarding demographics, medical history and details on exercise habits (metabolic equivalent hours/week, exercise intensity, duration and frequency). Physical activity level was expressed in metabolic equivalent value of activity according to the Compendium of Energy Expenditures for Youth [15]. Furthermore, body weight and height were measured by an electronic scale and height stadiometer, respectively.

2.5.2. Maximal voluntary isometric contraction of leg muscles

To compare muscle activation patterns across participants, the maximal voluntary isometric contractions (MVIC) was first measured for rectus femoris, biceps femoris, tibialis anterior and gastrocnemius medialis of the right leg. MVIC testing methods were based on a standardized manual [16] where each muscle was measured twice, with a 1-minute recovery period in between, in a seated position [17]. Raw EMG data was bandpass filtered (20 to 460 Hz) and sampled at a rate of 1000 Hz (amplified by a gain factor of 1000), and then root mean squared (RMS) where the highest EMG_{rms} values were extracted from the two trials and averaged for subsequent data normalization.

2.5.3. YBT-LQ and lower limb EMG activity measurements

All participants performed the YBT-LQ by using the Y-Balance Test Kit™ (Move2Perform, Evansville, IN, USA). Surface EMG electrodes (EMG sensor SX230-1000, Biometrics, Newport, UK) were placed on prepped skin. The circular-shaped Ag/AgCl bipolar surface EMGs with an interelectrode distance of 2 cm were applied to the test limb's rectus femoris, biceps femoris, tibialis anterior and gastrocnemius medialis muscles [18]. Foot pressure sensors (FS4 contact switch assembly, Biometrics, Newport, UK) were placed at the base of calcaneus and the base of the first metatarsal of the test limb to register the start of each YBT-LQ trial. The test limb (i.e., weight-bearing limb) was determined as the dominant limb which unilateral recording method was adopted in a previous study [19]. During each YBT-LQ trial, raw EMG data was collected simultaneously. The collected EMG raw data were recorded set at a bandwidth of 20–460 Hz and amplified at a rate of 1000 Hz, with an input impedance at $> 10^{15}\ \Omega$ and common mode rejection

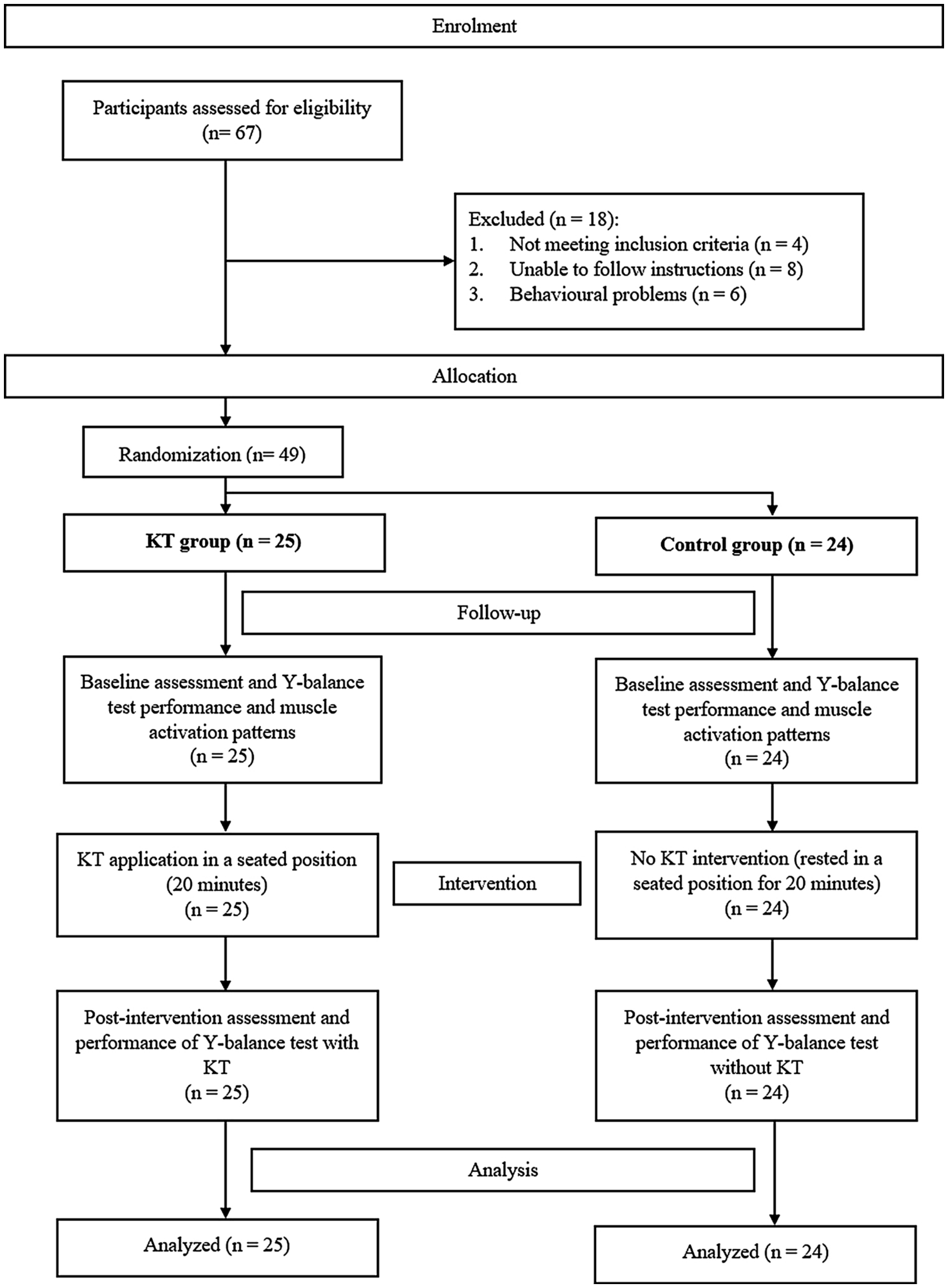

Fig. 1. CONSORT flowchart.

ratio > 96 dB. The ipsilateral tibial tuberosity was chosen as the reference electrode (R506, Biometrics, Newport, UK) location. All equipment was secured with adhesive tape to the skin and wires were bundled and connected to a DataLOG device at the waist level. Data was subsequently processed through the Biometrics EMG analysis software for DataLOG version 8.51 (Newport, UK).

Prior to the six practice trials and official trials of YBT-LQ, a physiotherapist demonstrated each direction with verbal instructions referenced from the Move2Perform website to each participant. *Participants were instructed to push the reach indicator as far as possible at their own pace with the non-weight-bearing limb while keeping their balance.* Three official trials were performed for each direction after the practice trials in the following order: (i) anterior (AT); (ii) posteromedial (PM); and (iii) posterolateral (PL). The maximum reach distance of each successful trial was recorded to the nearest one decimal place and averaged subsequently. The trial was discarded and repeated if the participant (i) kicked/stepped on the reach indicator; (ii) touched the floor at any instance during the trial; or (iii) lost balance.

2.6. Outcome measures

2.6.1. Primary outcome measures

2.6.1.1. YBT-LQ normalized scores. The normalized scores of each reach direction was scaled to the participant's leg length. A total of three successive trials were averaged for the normalized mean reach distance. The composite score was calculated with the following equation:

$$Composite\ score = \left[\frac{(AT + PM + PL)}{(Leg\ length \times 3)}\right] \times 100$$

2.6.2. Secondary outcome measures

2.6.2.1. Lower limb muscle peak activation. The peak EMG_{rms} value for

Fig. 2. Kinesio tape application on the rectus femoris muscle.

Fig. 3. Kinesio tape application on the gastrocnemius muscle.

each YBT-LQ trial and reach direction from three successful trials was extracted from a 100-millisecond window to be averaged. To compare values across participants, averaged values were normalized to the MVIC RMS values of the muscle to be expressed in percentage of MVIC (%MVIC) [20].

2.6.2.2. Time-to-peak EMGrms value of lower limb muscles. The non-weight-bearing limb's starting position was placed with sole contacting the ground. The pressure sensors were located at the base of calcaneus and base of first metatarsal of the non-weight-bearing limb to register the start of the trial when the entire sole left the ground after the verbal cue. The time-to-peak EMG duration (ms) was determined from the onset of foot pressure sensor signal to the peak EMG_{rms} of each muscle.

2.7. Statistical analyses

The sample size calculation was performed by the G*Power version 3.1.0 software (Franz Faul, Universität Kiel, Germany). A previous study investigated the acute effect of KT on lower limb strength and balance measures with medium effect sizes ranging from 0.75-0.94 [21]. Therefore, an effect size of 0.85 was chosen for this study with the statistical power set at 80% and an alpha level at 5% (two-tailed). Assuming no one dropped out (as participants visited our laboratory once only), a minimum of twenty-three participants were required for each group.

The Statistical Package for Social Science 23.0 (IBM, Armonk, NY) was used for statistical analysis. The normality criterion was checked by using the Shapiro-Wilk test and histogram. Baseline demographic and outcome variable differences between the two groups were determined by using the independent *t*-test (continuous data) and chi-square (categorical data) accordingly. The overall effect of KT on YBT-LQ performance and EMG outcomes were examined by using two-way repeated measure analysis of covariance. MVIC and EMG patterns may be a potential covariate(s) with significant variability across subjects [3]. The within- and between-subject factors were set as time and group, respectively. Intention-to-treat approach was used to minimize dropout effects, if any. Post-hoc independent *t*-test and paired *t*-test were performed to the outcomes with significant group, time or time-by-group interaction effects. The overall alpha level was set at 5% (two-tailed).

3. Results

3.1. Participants

From March to October 2016, sixty-seven children with DCD were recruited where they were screened by two physiotherapists for eligibility. Forty-nine qualified participants were randomly assigned to the KT group (n = 25) and control group (n = 24) (Fig. 1). All children were able to complete all testing trials successfully accordingly with no dropout. Table 1 illustrates the baseline demographic characteristics of the participants. No significant between-group differences were found between the two groups ($p > 0.05$). The muscle peak EMG_{rms} (% MVIC) for rectus femoris during PL direction at baseline was treated as a covariate due to a significant difference between the two groups at baseline ($p = 0.037$).

Table 1
Baseline characteristics of participants with DCD.

	KT group (n = 25)	Control group (n = 24)	p value
Age (years)	8.18 ± 1.16	8.06 ± 0.93	0.696
Sex			0.520
Male (n)	17	19	
Female (n)	8	5	
Height (cm)	125.40 ± 10.47	128.33 ± 8.70	0.292
Body weight (kg)	24.93 ± 6.18	27.75 ± 7.87	0.169
Body mass index (kg/m^2)	15.69 ± 2.36	16.59 ± 3.28	0.272
Leg length (cm)	64.74 ± 6.84	65.19 ± 6.77	0.819
MABC-2 (percentile)	7.26 ± 5.74	9.23 ± 6.19	0.254
Manual dexterity (percentile)	12.46 ± 15.53	14.52 ± 17.02	0.660
Aiming & catching (percentile)	11.24 ± 15.09	8.52 ± 11.61	0.484
Balance (percentile)	26.18 ± 22.70	33.60 ± 28.51	0.318
Physical activity level (metabolic equivalent hours/week)	10.71 ± 10.26	8.05 ± 5.23	0.261
Comorbid conditions (n, %)			0.143
Attention deficit hyperactivity disorder	0 (0.0)	2 (8.3)	
Autism spectrum disorder	4 (16.0)	1 (4.2)	
Dominant lower limb			
Right (n, %)	24 (96.0)	24 (100.0)	
Left (n, %)	1 (4.0)	0 (0.0)	
EMG MVIC values (μV)			
Quadriceps	3.00 ± 0.86	2.75 ± 0.95	0.341
Hamstring	3.09 ± 1.00	3.11 ± 1.01	0.929
Tibialis anterior	3.91 ± 1.36	3.75 ± 1.23	0.680
Gastrocnemius	2.09 ± 1.19	1.82 ± 0.93	0.381

Means ± standard deviations are presented (unless otherwise specified).
KT: Kinesio Taping; DCD: developmental coordination disorder; MABC-2: Movement Assessment Battery for Children 2nd edition; EMG: electromyography; MVIC: maximal voluntary isometric contraction.

Table 2
Comparison of Y-balance test normalized scores between the KT and control groups.

Y-balance test normalized scores	KT group (n = 25)			Control group (n = 24)			Between-group mean difference at posttest	p value		
	Pretest	Posttest	Within-group mean difference (pre - post) (95% CI)	Pretest	Posttest	Within-group mean difference (pre - post) (95% CI)	(KT - control) (95% CI)	Group effect	Time effect	Group × time effect
Anterior	39.70 ± 6.65	40.92 ± 8.07	−1.22 (-3.265, 0.825)	40.21 ± 7.47	39.32 ± 8.34	0.89 (-1.767, 3.538)	1.60 (-3.120, 6.314)	0.461	0.600	0.157
Posteromedial	57.20 ± 12.20	60.68 ± 13.21	−3.48 (-7.699, -2.301)	60.04 ± 11.56	60.08 ± 13.55	−0.04 (-6.148, -0.143)	0.60 (-6.251, 10.792)	0.727	0.987	0.104
Posterolateral	55.83 ± 12.59	60.83 ± 14.38	−5.00 (-5.861, -1.099)	55.42 ± 13.42	58.56 ± 15.27	−3.14 (-4.054, 3.971)	2.27 (-7.095, 8.288)	0.424	0.195	0.319
Composite Score[d]	77.79 ± 16.25	82.69 ± 18.41[c]	−4.90 (-7.308, -2.480)	79.62 ± 12.15	79.83 ± 14.08	−0.21 (-3.846, 3.427)	2.86 (-6.589, 12.307)	0.641	0.558	0.030[a]

KT: Kinesio Taping; DCD: developmental coordination disorder; MVIC: maximal voluntary isometric contraction; EMG_{rms}: electromyographic root mean squared value.
Group-by-time interaction effect:
[a]Denotes a significant group-by-time interaction effect ($p < 0.05$).
Between-group effect:
[b]Denotes a significant difference at $p < 0.05$ when compared with the control group.
Within-group effect:
[c]Denotes a significant difference at $p < 0.05$ when compared with the pre-test value.
Remarks:
[d]Composite score = [(anterior + posterolateral + posteromedial) / (leg length × 3)] × 100.

3.2. Primary outcome measures

3.2.1. YBT-LQ normalized scores

After KT application, the composite score revealed a significant group × time interaction effect (p = 0.030). The YBT-LQ composite score increased by 4.90 points compared to the baseline value in the KT group *(p < 0.001)*. However, the between-group difference at posttest was not significant *(p > 0.05)*. Individual reach direction did not reveal within- or between-group differences in either groups (Table 2).

3.3. Secondary outcome measures

3.3.1. EMG_{rms} peak muscle activation

During the AT and PM directions, rectus femoris peak muscle activation illustrated a significant group × time interaction effect (p = 0.039 and p = 0.005, respectively). The KT group exhibited a higher activation than the control group for posttest-values *(p = 0.023 and p = 0.042, respectively)*. When comparing posttest to pretest values, both KT and control groups revealed an increase in rectus femoris activation for AT *(p < 0.001 and p = 0.011, respectively)* and PM *(p = 0.010 and p = 0.029, respectively)* directions. Biceps femoris, tibialis anterior and gastrocnemius medialis peak muscle activation for AT and PM directions did not reveal any significant group, time, or group-by-time interaction effect. No significant group, time, or group-by-time interaction effects were illustrated in all muscles for the PL reach direction (Table 3).

3.3.2. EMG time-to-peak

For PM direction, there was a significant group × time interaction effect for the gastrocnemius medialis time-to-peak duration *(p = 0.008)*. The post-hoc test revealed a significant between-group difference *(p = 0.048)* where KT group had a 1.50 ms longer duration than the control group for posttest values. Findings showed a 1.32 ms decrease in gastrocnemius medialis time-to-peak duration from pretest values in the control group *(p = 0.043)* but not in the KT group. No significant group, time, and group-by-time interaction effects were noted in the remaining secondary outcome variables (Table 3).

4. Discussion

Our results demonstrated that KT improved YBT-LQ performance and *muscle activity (peak and time-to-peak)* of children with DCD. The results are in line with previous studies that revealed KT applied on quadriceps and gastrocnemius muscles could increase and preserve reach distances during the star excursion balance test (SEBT) in healthy individuals [22,23]. It is because the application of KT provides tactile stimulation to the cutaneous receptors, more specifically the Ia afferent fibres [24]. This increases the gamma motor neuron activities which alters muscle activation patterns [10,25]. The improvement in composite score confirms the immediate beneficial effects of KT on dynamic balance control in children with DCD. However, the posttest values for KT group were not significantly different from the control group suggesting that other factors may contribute to this.

The magnitude of balance improvement may be influenced by the duration of KT application where effects were detected as early as immediately after application to 24–72 hours post KT removal [11,21–23]. Nakajima et al. [22] found that KT improved SEBT performance 24-hours post application but not immediately. The varied effects of KT during different time periods could be attributable to the alteration of muscle tone due to a reflex effect on the nervous system [11]. We elucidate a longer KT duration may enhance the cutaneous stimulation for more prominent and YBT-LQ reach-direction-specific effects.

The application of KT increased rectus femoris peak muscle activation and the posttest outcome values were significantly greater than that of the control group. During YBT-LQ, the knee is flexed at 60° to

Table 3
Comparison of EMG outcome measures between the KT and control groups.

Muscle peak EMG_{rms} (%MVIC) for Y-balance test	KT group (n = 25) Pretest	KT group Posttest	KT group Within-group mean difference (pre - post) (95% CI)	Control group (n = 24) Pretest	Control group Posttest	Control group Within-group mean difference (pre - post) (95% CI)	Between-group mean difference at posttest (KT - control) (95% CI)	p value Group effect	p value Time effect	p value Group × time effect
Anterior										
Rectus femoris	23.46 ± 13.68	55.96 ± 36.84[b,c]	−32.50 (-48.619, -16.395)	23.18 ± 13.43	36.08 ± 19.33[c]	−12.90 (-22.544, -3.251)	19.88 (2.868, 36.898)	0.018	0.113	0.039[a]
Biceps femoris	34.44 ± 15.86	72.22 ± 33.91	−37.78 (-51.569, -23.998)	29.29 ± 15.22	55.47 ± 26.99	−26.18 (-38.836, -13.537)	16.75 (-0.912, 34.410)	0.012	0.140	0.102
Tibialis anterior	44.18 ± 24.33	76.58 ± 35.39	−32.40 (-49.629, -15.173)	49.06 ± 30.33	84.22 ± 35.67	−35.16 (-53.676, -16.657)	−7.64 (-28.064, 12.786)	0.005	0.708	0.714
Gastrocnemius medialis	66.46 ± 42.14	181.51 ± 137.85	−115.05 (-174.337, -55.767)	74.51 ± 45.38	187.11 ± 143.36	−112.60 (-172.446, -52.753)	−5.59 (-86.409, 75.222)	0.574	0.001	0.952
Posteromedial										
Rectus femoris	46.56 ± 25.15	71.17 ± 41.10[b,c]	−24.61 (-42.631, -6.591)	61.20 ± 22.39	48.55 ± 34.20[c]	12.65 (1.445, 23.846)	22.62 (0.838, 44.391)	0.005	0.037	0.005[a]
Biceps femoris	60.50 ± 25.21	54.57 ± 29.84	5.93 (-11.037, 22.899)	56.11 ± 22.59	48.67 ± 33.63	7.44 (-4.859, 19.739)	5.90 (-12.356, 24.152)	0.271	0.169	0.672
Tibialis anterior	95.55 ± 59.93	96.94 ± 34.09	−1.39 (-28.133, 25.353)	121.66 ± 57.67	94.73 ± 41.70	26.93 (2.646, 51.211)	2.21 (-19.641, 24.055)	0.542	0.453	0.120
Gastrocnemius medialis	130.29 ± 86.70	156.59 ± 114.64	−26.30 (-85.479, 32.867)	145.86 ± 105.26	155.80 ± 125.47	−9.94 (-85.126, 65.251)	0.79 (-72.104, 73.694)	0.901	0.163	0.985
Posterolateral										
Rectus femoris	62.82 ± 33.00	68.03 ± 40.16	−5.21 (-21.696, 11.279)	55.17 ± 19.98	54.43 ± 24.80	0.74 (-11.747, 13.220)	13.60 (-5.685, 32.870)	0.019	0.076	0.966
Biceps femoris	59.59 ± 24.27	53.75 ± 29.31	5.84 (-6.888, 18.550)	66.40 ± 40.23	55.91 ± 34.85	10.49 (-9.261, 30.242)	−2.16 (-20.636, 16.321)	0.706	0.023	0.334
Tibialis anterior	102.76 ± 42.90	102.88 ± 45.36	−0.12 (-23.421, 23.169)	124.95 ± 58.64	100.00 ± 38.60	24.95 (-3.849, 53.746)	2.88 (-21.373, 27.133)	0.519	0.350	0.152
Gastrocnemius medialis	130.76 ± 74.89	163.65 ± 114.08	−32.89 (-87.044, 21.268)	156.40 ± 96.02	151.66 ± 85.27	4.74 (-38.287, 47.764)	11.99 (-46.085, 70.059)	0.775	0.398	0.379
Time-to-peak EMG (ms) for Y-balance test										
Anterior										
Rectus femoris	3.28 ± 1.61	4.22 ± 3.10	−0.94 (0.648, -2.285)	3.65 ± 2.71	4.53 ± 4.32	−0.88 (-2.784, 1.021)	−0.31 (-2.460, 1.852)	0.671	0.782	0.861
Biceps femoris	2.91 ± 1.86	3.39 ± 3.25	−0.48 (-2.114, 1.151)	2.47 ± 2.11	3.70 ± 3.15	−1.23 (-2.955, 0.498)	−0.31 (-2.149, 1.534)	0.762	0.878	0.637
Tibialis anterior	2.90 ± 2.14	3.49 ± 3.82	−0.59 (-2.069, 0.895)	2.73 ± 1.87	3.39 ± 4.08	−0.66 (-2.808, 1.685)	0.10 (-2.172, 2.573)	0.457	0.520	0.731
Gastrocnemius medialis	3.11 ± 1.91	4.31 ± 2.95	−1.20 (-2.346, -0.059)	3.28 ± 2.56	3.84 ± 2.79	−0.56 (-1.712, 0.581)	0.47 (-1.186, 2.116)	0.709	0.477	0.414
Posteromedial										
Rectus femoris	3.40 ± 2.26	3.32 ± 2.89	0.09 (-0.727, 0.902)	3.99 ± 2.88	3.45 ± 3.68	0.54 (-0.719, 1.795)	−0.13 (-2.036, 1.760)	0.574	0.668	0.733

(*continued on next page*)

Table 3 (*continued*)

Muscle peak EMG_{rms} (%MVIC) for Y-balance test	KT group (n = 25)			Control group (n = 24)			Between-group mean difference at posttest (KT - control) (95% CI)	p value		
	Pretest	Posttest	Within-group mean difference (pre - post) (95% CI)	Pretest	Posttest	Within-group mean difference (pre - post) (95% CI)		Group effect	Time effect	Group × time effect
Biceps femoris	3.70 ± 2.58	4.42 ± 3.69	−0.72 (-2.217, 0.786)	3.90 ± 2.25	4.00 ± 3.99	−0.10 (-1.826, 1.632)	0.42 (-1.788, 2.627)	0.887	0.409	0.725
Tibialis anterior	2.91 ± 2.46	4.01 ± 3.60	−1.10 (-2.392, 0.196)	3.43 ± 2.98	3.24 ± 3.48	0.19 (-1.153, 1.527)	0.77 (-1.264, 2.808)	0.823	0.530	0.210
Gastrocnemius medialis	2.54 ± 1.51	3.94 ± 3.21[b]	−1.40 (-2.837, 0.045)	3.76 ± 2.69	2.44 ± 1.70[c]	1.32 (0.042, 2.588)	1.50 (0.015, 2.983)	0.679	0.988	0.008[a]
Posterolateral										
Rectus femoris	3.60 ± 2.57	3.80 ± 3.25	−0.20 (-1.572, 1.173)	3.53 ± 2.95	3.88 ± 4.63	−0.35 (-2.317, 1.605)	−0.08 (-2.378, 2.206)	0.773	0.323	0.696
Biceps femoris	4.18 ± 2.72	3.63 ± 2.70	0.55 (-0.362, 1.466)	4.13 ± 2.73	4.19 ± 4.48	−0.06 (-1.789, 1.671)	−0.56 (-2.671, 1.559)	0.989	0.300	0.304
Tibialis anterior	3.22 ± 2.58	3.28 ± 3.20	−0.06 (-1.131, 1.000)	2.51 ± 2.21	3.41 ± 4.69	−0.90 (-2.998, 1.206)	−0.13 (-2.423, 2.170)	0.448	0.142	0.284
Gastrocnemius medialis	2.98 ± 2.60	3.34 ± 2.12	−0.36 (-1.401, 0.678)	3.24 ± 2.12	3.92 ± 4.75	−0.68 (-2.360, 0.998)	−0.58 (-2.682, 1.515)	0.745	0.141	0.507

KT: Kinesio Taping; DCD: developmental coordination disorder; MVIC: maximal voluntary isometric contraction; EMG_{rms}: electromyographic root mean squared value.
Group-by-time interaction effect:
[a]Denotes a significant group-by-time interaction effect ($p < 0.05$).
Between-group effect:
[b]Denotes a significant difference at $p < 0.05$ when compared with the control group.
Within-group effect:
[c]Denotes a significant difference at $p < 0.05$ when compared with the pre-test value.

80° with the quadriceps contracting eccentrically to control the single-leg squat movement [20]. AT direction, in particular, has a relatively higher peak quadriceps muscle activation followed by PM and PL, respectively [20]. Interestingly, the higher the required quadriceps activity for the reach direction, the greater the amplitude of quadriceps increments were shown in our results. We postulated that the muscle deficits in children with DCD [2] may predispose the effects of KT influencing on muscle activity.

To the best of our knowledge, this is the first study to measure EMG changes with KT application during YBT-LQ. It would be insightful to compare studies assessed by different types of balance evaluations. Our results agree with the significant increase in quadriceps muscle activity assessed with single-leg hop test and kinesthetic ability trainer after the application of KT [12,26]. Furthermore, daily activities often incorporate various aspects of balance components. For instance, stair descent and YBT-LQ AT reach direction both involve lowering one's centre of mass in a single-leg stance position [27]. Chen et al. [28] reported that application of KT to the quadriceps increased the vastus medialis obliquus/vastus lateralis ratio during stair descent in patients with patellar femoral pain syndrome. Our study provides *insights* on the potential benefits of KT to not only dynamic balance tasks but specifically to YBT-LQ in children with DCD.

The KT group exhibited longer gastrocnemius medialis time-to-peak duration during PM direction when compared to the control group for posttest values. This reassures the previously reported KT's potential to influence muscle activity duration during gait in healthy individuals [21]. We elucidate the change of muscle activity duration in children with DCD be due to modulation of the skin stretch receptors to compensate for the less developed feedforward system [5,21]. A distinctive feature of YBT-LQ from stair descent is to control ankle plantarflexion at around 20° and having to apply pressure to the reach indicator [20]. Thus, an increase in gastrocnemius time-to-peak duration could be beneficial to YBT-LQ for subtle compensatory postural reactions.

The control group's gastrocnemius medialis time-to-peak duration decreased by 35% from pretest values which is comparable to the recently reported 27–37% shorter duration in children with DCD [5]. Although the time-to-peak duration for the KT group increased by 55% from pretest values, it did not reach a significant level. It is uncertain as to why other muscles did not reveal significant difference. Future research is warranted to investigate the influence of KT on muscle time-to-peak activation.

A limitation was that this study did not investigate the prolonged effect of KT and follow-up effect post KT removal. Determining the optimal KT application duration to enhance dynamic postural control will be essential to optimize balance rehabilitation for children with DCD. Secondly, placebo/sham tape group was not included in this study. Thus, one cannot determine the extent of the KT effect attributable to psychological components. The KT group may have had expectations about the benefits of KT, which may have introduced some biases in the outcomes [29]. Moreover, it is uncertain if applying KT over EMG electrodes alters its effectiveness which requires further investigation. Lastly, dynamic postural control can be measured in several forms of which YBT-LQ is one of them. Results should not be overgeneralized to other dynamic postural tasks.

5. Conclusions

The immediate effect of KT to improve YBT-LQ performance was non-specific to reach direction. This was accompanied with a significantly higher amplitude of rectus femoris muscle activity and a longer gastrocnemius medialis time-to-peak muscle activity. Therefore, children with DCD could benefit from using KT as an adjunct when performing dynamic postural control exercises.

Conflict of interest

None.

Acknowledgements

This work was partially supported by a grant from the Research Grants Council of the Hong Kong Special Administrative Region, China (17658516). The authors would like to thank the support of the following schools: Heep Yunn Primary School, Si Yuan School of the Previous Blood, TWGHs Hok Shan School, St Peter's Catholic Primary School, HHCKLA Buddhist Wisdom Primary School, Pun U Association Wah Yan Primary School, Emmanuel Primary School, SKH Tin Shui Wai Ling Oi Primary School and HKTA Yuen Yuen Institute Shek Wai Kok Primary School.

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