Effects of Extracorporeal Shock Wave Treatment on the Muscle Tone and Static Stability of Gastrocnemius Muscle according to the Energy Amount with Adolescent Cerebral Palsy

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Purpose This study investigates the effects of extracorporeal shock wave treatment on the muscle tone and static stability of gastrocnemius muscle according to the energy amount in adolescent with spastic cerebral palsy. ***Methods*** The low energy group(n=9) and high energy group(n=9) to which extracorporeal shock wave was applied were randomly selected. The muscle tones of all subjects were measured before intervention, immediately after intervention, and 5 min after intervention. The static stability was measured before intervention and 10 min after intervention. ***Results*** Muscle tone significantly decreased both in the group to which high energy extracorporeal shock wave was applied and the group to which low energy extracorporeal shock wave was applied. Muscle stiffness statistically significantly decreased only in the group to which high energy extracorporeal shock wave was applied ($p<.05$). The difference in the amount of change between the two groups was statistically significant only before intervention and immediately after intervention ($p<.05$). Furthermore, regarding static balance, the sway area measured with eyes open showed a statistically significant difference between the two groups ($p<.01$). The sway path length showed a statistically significant decrease 10 min after intervention only in the group to which high energy extracorporeal shock wave was applied. Thus, the inter-group change in sway path length showed a statistically significant difference ($p<.01$). ***Conclusion*** This result suggests that extracorporeal shock wave using a high energy is more effective than extracorporeal shock wave using low energy in the reduction of muscle tone in adolescent with spastic cerebral palsy.

Key Words Cerebral palsy, Gastrocnemius, Extracorporeal shockwave therapy, Muscle tone, Static stability

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Ⅰ. Introduction

Cerebral palsy is a non-progressive brain lesion of an immature brain that occurs before, at, or after birth in developing fetuses and infants, mainly accompanied by motor disturbances, sensory, and expressional disturbances, behavioral disturbances or convulsions.[1] Among children with cerebral palsy, spastic cerebral palsy cases account for the largest portion, approximately 80%.[2] Spastic cerebral palsy causes postural instability, decrease of motility, and leg stiffness.[3] Patients with cerebral palsy experience difficulty maintaining posture or moving, and exhibit talipes equinus.[4]

The ability to maintain balance is required when people try to perform activities of daily living or purposeful activities.[5] When the ability to perform activities of daily living improves with an increase of balance ability, life satisfaction increases with increased participation in activities.[6] Therefore, the balance ability is the most important factor for improvement in the quality of life in children with cerebral palsy.[7]

Rahimzadeh[8] claimed that muscle tone control is crucial because muscle tone influences balance ability. Park[9] reported that the lower the muscle tone of the gastrocnemius muscle, the higher the balance ability becomes. Treatments to reduce muscle tone include botulinum toxin injection and intrathecal drug therapy.

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There are still no satisfactory results in the treatment of stiffness because the effect of each treatment is different by patient and there are many adverse effects.[10] However, the effects of extracorporeal shock wave treatment have been researched until recently for reduction of muscle tone.[11] Extracorporeal shock wave treatment effective not only for treating hypertonia, but also for promoting nerve regeneration and restoring nerve transmission speed.[11] Prior studies that applied extracorporeal shock wave treatment to muscle tone have reported that subjects showed a decrease in muscle tone and an increase in the surface area of the foot, which also affected the stability of the body after extracorporeal shock wave intervention in the plantar flexor with hypertonia. [12] Uhm and Kim[13] reported that when extracorporeal shock wave was applied to stroke patients with hypertonia in gastrocnemius muscle, the balance ability improved by increased muscle activity and joint range of motion owing to a decrease in muscle tone.

As a noninvasive treatment, extracorporeal shock wave has been found to be effective in stiffness reduction.[14] Moreover, a study found that when different energy amount of shock wave were applied, high energy had a better effect on stiffness reduction than low energy.[15] The effects of extracorporeal shock wave applied adults on the reduction of muscle tone have been steadily researched.

The application of extracorporeal shock wave intervention to adolescent with spastic cerebral palsy have been studied, but few studies have applied different energy amount of shock waves and compared the results, or investigated the effects of muscle tone reduction through extracorporeal shock wave on static stability. Therefore, this study applied different energy amount of extracorporeal shock wave to t adolescent with spastic cerebral palsy who had low balance ability due to high muscle tone of the gastrocnemius muscle, and examined its effects on muscle tone and static stability. The findings of this study presents grounds for the statistically significant effect of extracorporeal shock wave on the treatment of adolescent with spastic cerebral palsy.

II. Material and Methods

1. Subjects

This study was conducted on adolescent with muscle stiffness in "D" Development Support Center located in Cheongju, Chungcheongbuk-do. A total of 18 subjects were randomly assigned to two groups to which different energy amount of extracorporeal shock wave were applied. The guardians of all the subjects sufficiently understood the method and content of this study and consented to participation in this study before the subjects participated in this study. It was sufficiently explained that the subjects can withdraw from this study at any time if it is against the will of the subjects and their guardians even during the progress of this study. The subjects were selected among adolescent diagnosed with spastic cerebral palsy, adolescent with grade 1-3 in the gross motor function classification system (GMFCS) adolescent,[16] with grade 1 or 2 in the modified Ashworth scale (MAS) for the paralyzed lower extremity stiffness,[17] teenage who can understand and follow the oral instructions of the therapist, and teenage who have not received botulinum toxin injection or orthopedic surgery within the last six months. The general characteristics of the subjects are outlined in Table 1.

Table 1. General characteristics of the subjects

Group	Gender (Male/Female)	Age (years)	Weight (kg)	Height (cm)	MAS (G1/ G1+/G2)	GMFCS (level1/level2)	Type (diplegia/ hemiplegia/ mixed)
Low energy group	(5/4)	14.1±5.1	39.3±14	139.3±14.6	1(11)/5(55)/3(33)	6(66)/3(33)	4(44)/2(22)/3(33)
High energy group	(4/5)	15.8±4.6	45.9±13.5	151.9±19.2	2(22)/6(66)/1(11)	7(77)/2(22)	5(55)/2(22)/2(22)

*p<.05

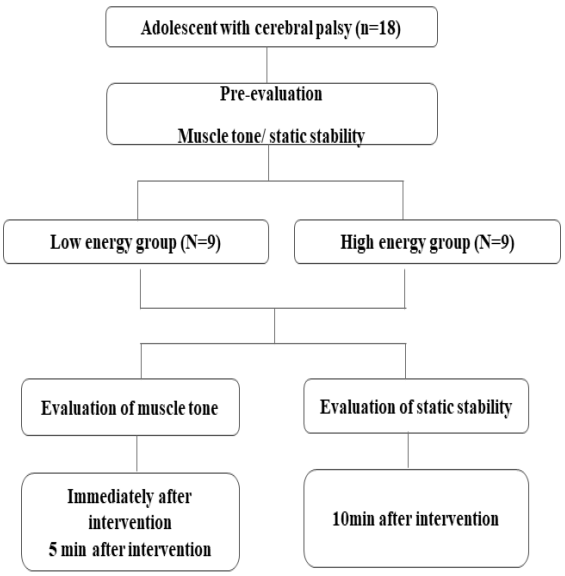

Figure 1. Study flow chart

2. Methods

Muscle tone and static stability were measured at baseline. After applying extracorporeal shock wave to the low and high energy groups, the muscle tones of the subjects were measured immediately after intervention and 5 min after intervention. In addition, the static stability was measured 10 min after intervention (Figure 1).

For the low energy group, the energy amount was set to 1.4 bar (0.07 mj/mm^2), the number of hits was set to 1500, and the frequency was set to 10 Hz. It was then applied to the muscle belly of the lateral head of gastrocnemius muscle where the muscle tone was higher.[18]

For the high energy group, the energy amount was set to 2.8 bar (0.14 mj/mm^2), the number of hits was set to 1500, and the frequency was set to 10 Hz. It was then applied to the muscle belly of the lateral head of gastrocnemius muscle where the muscle tone was higher. The subjects who complained of pain or redness of the skin were excluded from the high energy treatment (Figure 2).

3. Measurements

1) Muscle tone

The muscle tone and stiffness of adolescent with spastic cerebral palsy was measured using Myoton Pro

Figure 2. Extracorporeal shock wave

Figure 3. Myoton

(Myoton AS, Tallinn, Estonia). This instrument has a high reliability in the measurement of muscle tone and stiffness,[19] and allows fast and convenient measurement of the biomechanical properties of tissues in a noninvasive manner.[20] The measurements of muscle tone (Hz) and stiffness (N/m) were averaged and recorded. While the patient was in prone position with their feet stretched out of the bed, the muscle belly of the lateral gastrocnemius muscle was indicated with a marker that was harmless to the human body. It was then measured with the probe of the instrument by supporting it with both hands so that it would not deviate from the mark points and maintain a right angle to the muscle during five air vibrations.[21] After measuring the lateral gastrocnemius muscles of both sides with Myoton, the side with a higher muscle tone was evaluated (Figure 3).

2) Static stability

To measure the static stability at the center of pressure (COP) in standing position, we used Zebris (PDM Multifunction Force Measuring Plate; Zebris Germany) (Figure 4), a gait measuring instrument based on pressure distribution. This instrument dis-

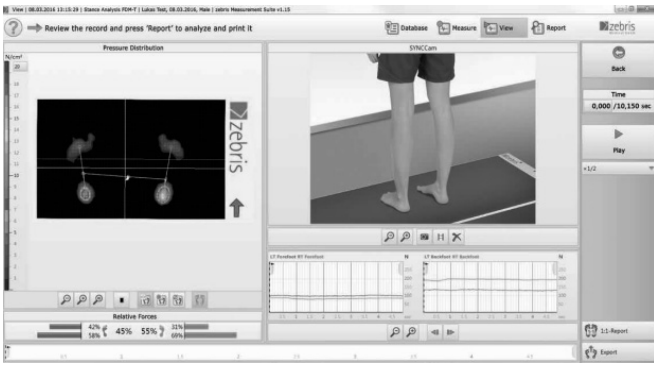

Figure 4. Zebris

plays the input pressure signals together with the COP as a 3D graph of spatiotemporal measurements while the subject is standing or walking, and shows a high reliability in the stride length two-foot stance phase.[22] The teenage were instructed to stand barefoot on the force measuring plate and stare at a doll 1.5 m in front of them. They were measured three times while maintaining the upright posture for 30 s. Next, they were measured three times using the same method while wearing an eye bandage. The average of the three measurements was used for evaluation, and the sway area (mm^2) and sway path length (mm) were recorded.

4. Data analysis

The data collected in this study were researched using SPSS 21.0 for Windows (IBM Corp, USA). The descriptive statistics were derived for the general characteristics of the subjects, and a non-parametric method was used after checking the normal distribution of the measured parameters through the Kolmogorov-smirnov test. The changes in muscle tone and stiffness according to the measurement time, that is, before, immediately after, and 5 min after intervention of the intervention of extracorporeal shock waves in each group were examined using the Friedman test. The differences in the changes in muscle tone and stiffness according to the measurement time between high and low energy groups were investigated using repeated measured ANOVA. The differences in changes between the two groups at different measurement time points were compared by performing a test of within subjects contrast. The changes in static stability between the two groups before and after intervention were verified using the Wilcoxon singed rank test. Finally, the differences in the changes before and after intervention between the two groups were analyzed using repeated measured ANOVA. The significance amount for the statistical hypothesis testing in this study was set to 0.05.

III. Results

1. Change in muscle tone according to energy amount

The low energy group did not show a statistically significant change of muscle tone, but the high energy group showed a statistically significant decrease in muscle tone by measurement time. Between the two groups, the high energy group also showed a more statistically significant difference in the decrease of muscle tone than the low energy group ($p < .05$) (Table 2). The test of within subjects contrast for the change of stiffness by measurement time according to

Table 2. Intragroup-intergroup change in muscle tone according to the energy amount (n=18)

Groups	Muscle tone (Hz)			*p*-value[1]
	pre intervention	Immediately after intervention	5 min after intervention	
Low energy group	14.70±2.29	13.79±2.07	14.26±2.27	0.074
High energy group	18.28±2.60	15.38±2.03	15.97±1.97	0.001*
F		5.054		
p-value[2]		0.039*		

p-value[1] : within a group, *p*-value[2]: between a group, value are Mean±SD, *$p<.05$

Table 3. Test of within subjects contrast for the change of muscle tone by measurement time between the two groups according to energy amount (n=18)

Factor*group	Type III Sum of Squares	Means Square	F	*p*-value
Levle[1] vs Level[2]	19.845	19.845	19.614	0.000*
Level[2] vs Level[3]	0.245	0.245	0.256	0.620

Factor: Muscle tone, Level[1]: pre, Level[2]: Immediately after intervention, Level[3]: 5 min after intervention, *p<.05

Table 4. Intragroup-intergroup changes in stiffness according to the energy amount (n=18)

	Stiffness (N/m)			*p*-value
	pre intervention	Immediately after intervention	5 min after intervention	
Low energy group	255.89±70.53	233.33±62.91	249.89±68.33	0.016*
High energy group	378.11±76.06	281.67±54.53	304.22±54.06	0.000*
F		6.431		
p-value[2]		0.022*		

p-value[1] : within a group, *p*-value[2]: between a group, value are Mean±SD, *p<.05

Table 5. Test of within subjects contrast for the change of stiffness by group and measurement time according to energy amount (n=18)

Factor*group	Type III Sum of Squares	Means Square	F	*p*-value
Levle[1] vs Level[2]	24568.056	24567.056	19.909	0.016*
Level[2] vs Level[3]	162.000	162.000	0.043	0.519

Factor: Muscle tone, Level[1]: pre, Level[2]: Immediately after intervention, Level[3]: 5 min after intervention, *p<.05

energy amount showed a statistically significant difference in the change in muscle tone between the two groups before intervention and immediately after intervention (p <.01). However, the intergroup change in stiffness between immediately after intervention and 5 min after intervention was not statistically significant (p >.01) (Table 3).

2. Change in stiffness according to the energy amount

Stiffness statistically significantly decreased in both low and high energy groups, but the intergroup difference was statistically significant as it decreased more in the high energy group than in the low energy group (p <.05) (Table 4). In the test of within subjects contrast for stiffness change by measurement time according to energy amount, the intergroup change in stiffness showed a statistically significant difference between before intervention and immediately after intervention (p <.01). However, the intergroup change in stiffness did not show a statistically significant difference between immediately after intervention and 5 min after intervention (p >.01) (Table 5).

3. Change in sway area according to the energy amount

With eyes open, both low and high energy groups showed a statistically significant decrease in the sway area 10 min after intervention compared to before intervention (p <.05), but the intergroup differences were not statistically significant (p>.05). With eyes closed, both low and high energy groups did not show statistically significant difference in the change of sway area between before intervention and 10 min after intervention. Furthermore, the intergroup difference in the change of sway area was statistically insignificant, either (p>.05) (Table 6).

Table 6. Change in sway area according to the energy amount (n=18)

		Sway area (mm²)		Z	*p*-value[1]
		Pre intervention	10 min after intervention		
Eyes open	low energy group	273.42±79.29	187.73±71.38	-2.437	0.015*
	high energy group	308.63±66.75	225.94±69.39	-2.091	0.037*
	F	2.251			
	p-value[2]	0.152			
Eyes closed	low energy group	326.09±99.14	240.38±116.31	-1.483	0.138
	high energy group	288.59±82.96	275.2433±69.71	-1.633	0.102
	F	0.001			
	p-value[2]	0.152			

p-value[1] : within a group, *p*-value[2]: between a group, value are Mean±SD, *p<.05

Table 7. Change in sway path length according to the energy amount (n=18)

		Sway path length (mm)		Z	*p*-value[1]
		Pre intervention	10 min after intervention		
Eyes open	Low energy group	192.28±39.44	196.30±42.29	-0.535	0.592
	High energy group	153.49±34.82	126.04±59.30	-1.989	0.047*
	F	9.064			
	p-value[2]	0.008			
Eyes closed	low energy group	199.16±66.09	194.81±54.02	-0.297	0.767
	high energy group	204.08±46.57	177.20±50.51	-1.683	0.092
	F	0.083			
	p-value[2]	0.777			

p-value[1] : within a group, *p*-value[2]: between a group, value are Mean±SD, *p<.05

4. Change in sway path length according to the energy amount

With eyes open, the low energy group did not show a statistically significant difference, but the high energy group showed a significant decrease in the sway path length 10 min after intervention compared to before intervention (p<.05). The intergroup difference also was statistically significant as the sway path length decreased more in the high energy group than in the low energy group (p<.05). In contrast, with eyes closed, both groups did not show a statistically significant difference in the change of sway path length between before intervention and 10 min after intervention. Furthermore, the intergroup difference in the change in sway area was not statistically significant, either (p>.05) (Table 7).

Ⅳ. Discussion

This study randomly selected 18 teenage with spastic cerebral palsy based on the MAS and GMFCS, and examined the effects of the application of extracorporeal shock wave on the muscle tone and static stability of each group. The 18 subjects were separately assigned to low energy group (n=9) and high energy group (n=9), and the treatment effects were verified by evaluating muscle tone before intervention, immediately after intervention, and 5 min after intervention, and by evaluating static stability before intervention and 5 min after intervention.

Children with spastic cerebral palsy do not have a sufficient range of motion and exhibit gait anomalies such as talipes equinus because of the dominant stiffness of gastrocnemius muscle.[23] Recent studies have applied extracorporeal shock wave treatment to patients with cerebral palsy, and reported its effectiveness on reducing muscle tone.[12,14]

A previous study on pediatric patients with spastic cerebral palsy reported that muscle tone improved more in the treatment group who received extracorporeal shock wave treatment simultaneously with physiotherapy than in the control group who only received general physiotherapy.[24)]

Furthermore, Lin[24)] applied an intervention of extracorporeal shock wave treatment at 2.0 bar, 10Hz, and 2000 hits to the hamstring muscle of patients with spastic cerebral palsy, and found a significant decrease in muscle tone when the results were evaluated by the MAS. Wang et al.[22)] also applied extracorporeal shock wave at 0.6 bar and 1500 hits once a week for 3 months in pediatric patients with spastic cerebral palsy, and found significant differences in the PROM and GMFCS. The present study also found significant differences in stiffness and muscle tone between before intervention and immediately after extracorporeal shock wave intervention for both groups. These results suggest that extracorporeal shock wave treatment is effective for reducing the muscle tone of patients with spastic cerebral palsy. In the present study, both low and high energy groups showed significant differences in muscle tone, and the difference in stiffness was only significant in the high energy group. Intergroup differences were also significant as the amount of decrease was larger in the high energy group than in the low energy group. In previous studies, applying extracorporeal shock wave treatment of low energy also had an effect on the improvement of muscle tone[12,14)], but the findings of the present study suggest that the effect of the treatment continued longer after the intervention in the high energy group than in the low energy group. Although the appropriate energy amount for reduction of muscle tone by extracorporeal shock wave treatment has not been clearly defined,[25,26)] there was a study that found that high energy was more effective for treatment in the clinical application for musculoskeletal disorders. Most studies used intervention with a low energy in pediatric patients in consideration of adverse reactions such as psychological anxiety, redness, and pain. However, this study could treat the patients with a high energy without adverse reactions. Hence, using a high energy is considered to be an effective treatment for adolescent with spastic cerebral palsy.

Because the stiffness of gastrocnemius muscle, one of the characteristics of children with spastic cerebral palsy, influences static stability, the reduction of muscle tone is crucial to improve static stability in the treatment of children with spastic cerebral palsy.[12)] Amelio et al[12)] reported that applying extracorporeal shock wave to soleus and gastrocnemius muscles resulted in a statistically significant difference in muscle tone and a larger total foot surface area, and affected posture and body stability. In the Zebris test for evaluating static stability, sway area with eyes open showed a statistically significant decrease in both low and high energy groups, but the change of sway path length was statistically significant only in the high energy group. The reason for this is considered to be that the shockwave intervention of the high energy maintained the reduction of gastrocnemius muscle tone longer than that of the low energy, thus affecting static energy as well. Furthermore, although the intergroup difference in static stability was not statistically significant, using a high energy in treatment is believed to be better because it showed a better effect in the high energy group than in the low energy group.

Previous studies[12,22,27)] used the subjective evaluation methods of therapist such as MAS and PROM through extracorporeal shock wave intervention. However, the present study could perform measurements faster with a shorter measurement time and has a higher reliability than other evaluation methods because it uses the Myoton Pro instrument, which can detect even fine changes.[28)]

From the result of this study, it was found that the extracorporeal shock wave treatment using a high energy is more effective in the reduction of muscle tone in teenage with spastic cerebral palsy, and this is believed to have affected static stability by increasing the mobility of the ankle joint.

Therefore, based on the result of this study, extracorporeal shock wave intervention with high energy is more effective in the reduction of muscle tone in teenage with spastic cerebral palsy, and this is effec-

tive for static stability as well. It is expected that more significant effects could be obtained if high energy extracorporeal shock wave is applied to the treatment for muscle tone reduction to improve the static stability of pediatric patients in clinical settings.

Shortening of the Gastrocnemius muscle limits the rage of dorsiflexion motion and limits the postural strategies used for balance ability.[29] In particular, when the Gastrocnemius muscle is shortened severely, problems such as asymmetric posture, reduced balance and walking ability, and decreased ability to control movement occur,[30] and as the dorsiflexion angle is reduced, a problem occurs in the pressure of the foot.[31] Considering this point, extracorporeal shock wave was applied to reduce the muscle tone of the Gastrocnemius muscle, but it did not show a significant difference ins static balance.

This study has a few limitations. First, only the immediate effects of one intervention were examined, and follow-up observations were not made. Second, it was difficult to treat some teenage because they feared or could not endure the noise of extracorporeal shock wave, or refused to cover their eyes for measurement or showed anxiety. Lastly, although extracorporeal shock wave treatment is affected by the number of treatments,[32] this study could not observe the continuity of treatment effects due to the short intervention period.

The effects and usefulness of extracorporeal shock wave treatment in various diseases have been demonstrated, but guidelines to the standard treatment are insufficient.[33] Therefore, in order to comprehensively apply extracorporeal shock wave treatment using a high energy, the patient groups of teenage with spastic cerebral palsy should be subdivided and the limitations of this study should be improved in future studies to obtain more significant results of comparison.

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