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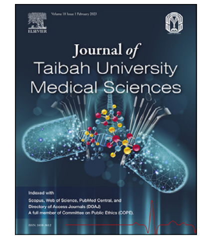

Original Article

Temporal effects of two interferential current applications on peripheral circulation in children with hemiplegic cerebral palsy

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الملخص

أهداف البحث: تحديد التأثيرات قصيرة المدى للتنبيه السمبثاوى و السطحى للتيار التداخلي على تدفق الدم لدى الأطفال المصابين بالشلل الدماغي الفالج.

طرق البحث: تم تقسيم 30 طفلا مصابين بالشلل الدماغي الفالج تتراوح أعمارهم بين 8 و 12 سنة عشوائيا إلى ثلاث مجموعات (10 أطفال لكل مجموعة). تلقت المجموعة الأولى التحفيز السمبثاوى للتيار التداخلي، وتلقت المجموعة الثانية التحفيز السطحى للتيار التداخلي، والمجموعة الثالثة (ضابطة) تلقت تحفيزا سطحيا وهميا للتيار التداخلي. تم تطبيق تردد 80-100 هرتز، وشدة 10-20 مللي أمبير لمدة 20 دقيقة. تم قياس سعة نبض حجم الدم باستخدام مستشعر التحجم في إصبع القدم الكبير قبل تطبيق التيار التداخلي، مباشرة بعد التحفيز وبعد 15 دقيقة، تم تحليل البيانات ومقارنتها إحصائيا.

النتائج: كان هناك فرق معتد به إحصائيا في سعة النبض في حجم الدم بين الفترات الزمنية الثلاث في كل من مجموعتي التحفيز السمبثاوى و السطحى ، مع عدم وجود فرق في المجموعة الضابطة. كانت هناك زيادة كبيرة في سعة النبض في حجم الدم مباشرة بعد التحفيز مقارنة بما قبل التحفيز في مجموعتي التحفيز السمبثاوى و السطحى. ومع ذلك، الأختلافات بين مجموعتي التحفيز السمبثاوى و السطحى في الفترات الثلاث المقاسة ليست ذات دلاله أحصائية.

الاستنتاجات: كان لكل من تطبيقى التيار التداخلي تأثير مناسب في تحسين تدفق الدم لدى الأطفال المصابين بالشلل الدماغي الفالج مع عدم وجود فرق في الفعالية بين التحفيز السمبثاوى و السطحى.

الكلمات المفتاحية: الجهاز العصبي اللاإرادي؛ الدورة الدموية؛ الشلل الدماغي؛ تحفيز كهربائي؛ شلل نصفي؛ تخطيط التحجم

Abstract

Objectives: To determine the short-term effects of sympathetic and peripheral stimulation of interferential current (IFC) on blood flow (BF) in children with hemiplegic cerebral palsy (CP).

Methods: Thirty children with hemiplegic CP, ranging from 8 to 12 years old, were randomly divided into three groups (10 children/group). The first group received sympathetic stimulation of IFC, the second group received peripheral stimulation of IFC, and the third group (control) received placebo peripheral stimulation of IFC. A frequency of 80–100 Hz at an intensity of 10–20 mA was applied for 20 min. Blood volume pulse (BVP) amplitude was measured before IFC application using a plethysmography sensor at the big toe immediately after and 15 min poststimulation. The data were statistically analyzed and compared.

Results: There were statistically significant differences in BVP amplitude among the three time intervals in both the sympathetic and peripheral groups ($P < 0.05$) with no difference in the control group ($P = 0.995$). There was a significant increase in BVP amplitude immediately after stimulation compared with before stimulation in both the sympathetic and peripheral groups ($P = 0.0001$). However, differences between the sympathetic and peripheral groups at the three measured periods were statistically nonsignificant ($P > 0.05$).

Conclusion: Both IFC applications had a proper effect on improving BF in children with hemiplegic CP with no difference in efficacy between sympathetic and peripheral stimulation.

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Keywords: Autonomic nervous system; Blood circulation; Cerebral palsy; Electrostimulation; Hemiplegia; Plethysmography

Introduction

The autonomic nervous system (ANS), both sympathetic and parasympathetic, plays a crucial role in maintaining physiological homeostasis and shaping physiological responses to acute stress.[1]

The primary function of the sympathetic system is to divert blood flow (BF) from the gastrointestinal tract and skin via vasoconstriction to the skeletal muscles and cardiorespiratory system. It also elevates heart rate and cardiac muscle contractility, resulting in an increase in BF to the skeletal muscles, which in turn results in increased BF to the coronary vessels of the heart via vasodilation.[2]

The regulation of skeletal muscle BF is important as it is essential for body functions such as locomotion. Contracting muscle consumes large amounts of oxygen to replenish adenosine triphosphate that is hydrolyzed during contraction; therefore, contracting muscle needs to be able to increase its BF and oxygen delivery to support its metabolic and contractile activities. Changes in BF correlate with motor unit firing rate modulation.[3]

Cerebral palsy (CP) is the most prevalent neurodevelopmental motor disorder in children. The global incidence of CP is between 2 and 2.5 cases per 1000 births.[4] Spastic CP in children may be accompanied by higher sympathetic vasomotor tonicity resulting from lesions in specific brain sites that can cause peripheral blood vessel vasoconstriction and constrain the cutaneous BF.[5] They also had capillary density 38% lower than the capillary density of healthy subjects. Ponten and Stal[6] reported that the low percentages of oxidative fibers, as well as the poor capability for oxidation and limited capillary supply to spastic muscles, contribute to higher exhaustion.

Cold extremities, pain, constipation, and sleeping disorders may also be linked to dysfunction of the ANS in children with CP. Sympathetic fibers control skin BF in the hands and feet, and the relationship between pain and low skin temperature might be due to high tone in sympathetic vasoconstriction fibers.[7]

After a stroke, hemiplegic extremities may lower vascular tone due to autonomic vasomotor dysfunction; nevertheless, prolonged inactivity in the paretic extremities may result in vasoconstriction due to reduced shear flow. In hemiplegic individuals, clinical observations indicate that the paretic extremities have lower skin temperature than the nonparetic extremities. Furthermore, impairment of the cutaneous microcirculation is more apparent in edematous extremities than in nonedematous extremities.[8] Metabolic milieu alteration in tissues on the side that is involved in chronic hemiparesis ultimately compromises the vasomotor function of the affected side.[9]

The pathological thermoregulation of patients with CP leads to a stronger cooling down, which may be the cause of different diseases. Trophic disorders such as reduced skin blood circulation are a well-known epiphenomenon of CP. The lower levels of leg vascularization may contribute to muscle spasticity and contractures.[10] They can influence quality of life and can lead to skin damages and, as a consequence, increase risk of decubitus. Therefore, it is important to analyze the volume change by BF in patients with CP. The knowledge on problems with skin blood circulation and increased warm-up times should be noticed by people who take care of persons with disabilities especially patients with lower mobility level.[11]

BF is used as the typical measurement for assessing vascular tone and thus the sympathetic vasomotor system. Photoplethysmography (PPG) is a noninvasive, low cost, and convenient diagnostic tool that uses infrared light to assess BF. Because red light is primarily absorbed by the hemoglobin in red blood cells and reflected by other tissues, the amount of light that returns to the PPG photodetector is proportional to the relative volume of blood circulating in the tissue under investigation.[12,13]

By using interferential current (IFC) electrical stimulation, the ANS blood vessel size regulation and flow velocity are adjusted.[14] The IFC makes use of two medium-frequency currents that run through the tissues at the same time. They have been set up in such a way that their paths overlap, and as a result, they interfere with one another. This interference results in the creation of an interloping or beat frequency that has features of low-frequency stimulation and is used to stimulate the brain.[15]

Cold extremities and poor peripheral BF found in children with CP are relatively associated with the malfunction of ANS.[11] Interferential electrical stimulation that deeply penetrates the body may reinstate BF by sympathetic nervous system adjustment.[14,15]

Several studies have investigated the effect of IFC on BF in healthy individuals.[14,16,17] No studies have investigated the outcome of using IFC to enhance the peripheral BF in children with CP. Thus, the goals of the current study were to investigate the vasomotor efficacy of IFC on improving peripheral blood supply in children with hemiplegic CP using two different techniques and determine the best application when there is an imbalance in the peripheral blood supply.

Materials and Methods

Study design

This was a multiple group randomized controlled trial. Written informed consent was provided by the children's parents or caregivers.

Participants

This study was conducted in the National Institute of Neuromotor System from August 2020 to May 2021 in accordance with the Declaration of Helsinki. Thirty children with hemiplegic CP of both sexes with age ranging from 8 to

12 years were randomly selected from the pediatric outpatient clinic of Faculty of Physical Therapy, Cairo University and the National Institute of Neuromotor System and randomly allocated into three groups of equal numbers. All participating children received regular physical therapy treatment. They suffered from poor peripheral circulation and had manifestation of cold extremities and pain. They could follow simple commands and instructions. Their spasticity degree ranged from 1 to 2 according to the modified Ashworth scale[18]; they had level I and II according to the Gross Motor Function Classification System (GMFCS).[19]

Children with a history of epilepsy, skin disorders, infection, fever, neoplasm, and edematous lower extremities were excluded from the current study. The participants were randomly allocated to one of three groups: the sympathetic group underwent direct IFC stimulation on the thoracolumbar sympathetic chain, the peripheral group received peripheral stimulation of IFC on the lower half of the affected leg, and the control group received placebo stimulation on the lower half of the affected leg. Children in all groups participated in regular physical therapy treatment including: 1) flexibility exercises; 2) progressive strengthen exercises; 3) postural correction; 4) balance training; 5) coordination exercises; 6) righting, equilibrium, and protective reactions from standing; and 7) functional gait training. The treatment was applied for 1 h, two times per week.[20] Forty-two children were assessed for eligibility as shown in Figure 1. Thirty children were divided randomly into three groups, with assignments made by the lottery system (draw names from box). Each group comprised 10 children.

Instrumentation

A PPG blood volume pulse (BVP) biofeedback system (NeXus 10; Amsterdam, The Netherlands), which is considered a reliable research tool for the assessment and modification of peripheral blood volume by biofeedback applications (Medical Community Europe certified, United States Food and Drug Administration registered), was used to measure the changes in blood volume in the vessels using a BVP sensor.[21,22] The BVP amplitude was calculated from the raw BVP signal and represented the relative amount of blood flow. The measurement unit is mV, a good BVP signal, as measured by the NeXus Biofeedback equipment, produces an amplitude of 10−100 mV or higher. This is a relative measure that indicates whether BF is increasing or decreasing.[23] For treatment, IFC using the Etius electrotherapy apparatus (ASTAR, Bielsko-Biała, Poland) was used, which is a modern and ergonomic unit intended for use in electrotherapy. It has two independent treatment channels.[24]

Procedure

Preparation of children

All children were instructed to avoid eating at least 1 h before starting the measurements. All measures were taken in a temperature-controlled chamber in a physiotherapy clinic at the National Institute of Neuromotor System. Each child was instructed to lie down on a plinth without movement for 10 min to regulate the circulation and allow for the skin temperature to be like that of the room. After that, the skin was prepared by using isopropyl alcohol to clean it, remove dead skin cells, and minimize skin impedance.[14,25]

Assessment procedure

BF was assessed for all groups with a BVP sensor at the big toe of the affected leg before IFC application, immediately after and 15 min poststimulation, 3 min for each measure.[14,25]

Training procedure

For the sympathetic stimulation group, four padded electrodes were placed on the level of the first thoracic (T1) and second lumber (L2) paravertebral 2 cm to the spinous processes.[14] For the peripheral stimulation group, two channels were used on the affected side. In channel one, one padded electrode was positioned at the ankle joint below the medial malleolus, while the other was positioned on lateral malleolus of the affected leg. In channel two, both padded electrodes were placed on the medial aspect of the affected leg at the lower half of the tibial shaft.[25] The control group received placebo stimulation to the lower half of the tibial shaft of the affected side as in the peripheral stimulation group. The IFC was applied for 20 min with an intensity of 10−20 mA and frequency of 80−100 Hz.[17]

Data analyses

Statistical analyses using IBM SPSS statistics (version 24) was conducted at a significance level of $P \leq 0.05$. One-way analysis of variance (ANOVA) was used to compare (mean ± standard deviation [SD]) age, weight, and height among the three groups. The frequency distribution and chi-square test were used to compare sex, spasticity grade, and GMFCS among groups. A 3 × 3 mixed design multivariate ANOVA (MANOVA) was conducted to compare the BVP amplitude among groups and the three measured time periods. The Bonferroni correction test was utilized to analyze the differences within and between groups.

Results

Before analysis, the data were checked for normality and variance homogeneity. When comparing the demographic data regarding children participating in this study, there were no significant differences among the three groups in age ($P = 0.578$), weight ($P = 0.593$), and height ($P = 0.711$). There were also no significant differences among groups in sex ($P = 0.875$), grade of spasticity ($P = 0.699$), and GMFCS ($P = 0.861$) (Table 1).

Statistical analyses using a 3 × 3 mixed design MANOVA indicated that there were nonsignificant effects of the tested groups ($F = 2.782$, $P = 0.08$); however, there were significant effects for time ($F = 16.862$, $P = 0.0001$). Also, the interaction between groups and time was significant, indicating that the effect of the tested group on BVP amplitude (the dependent variable) was influenced by time ($F = 4.753$, $P = 0.002$). As shown in Table 2, when comparing the mean ± SD of the BVP amplitude for all groups, there were no significant differences among groups either before or after 15 min of electrical stimulation ($P > 0.05$), whereas there was a significant difference immediately after electrical stimulation ($P < 0.05$).

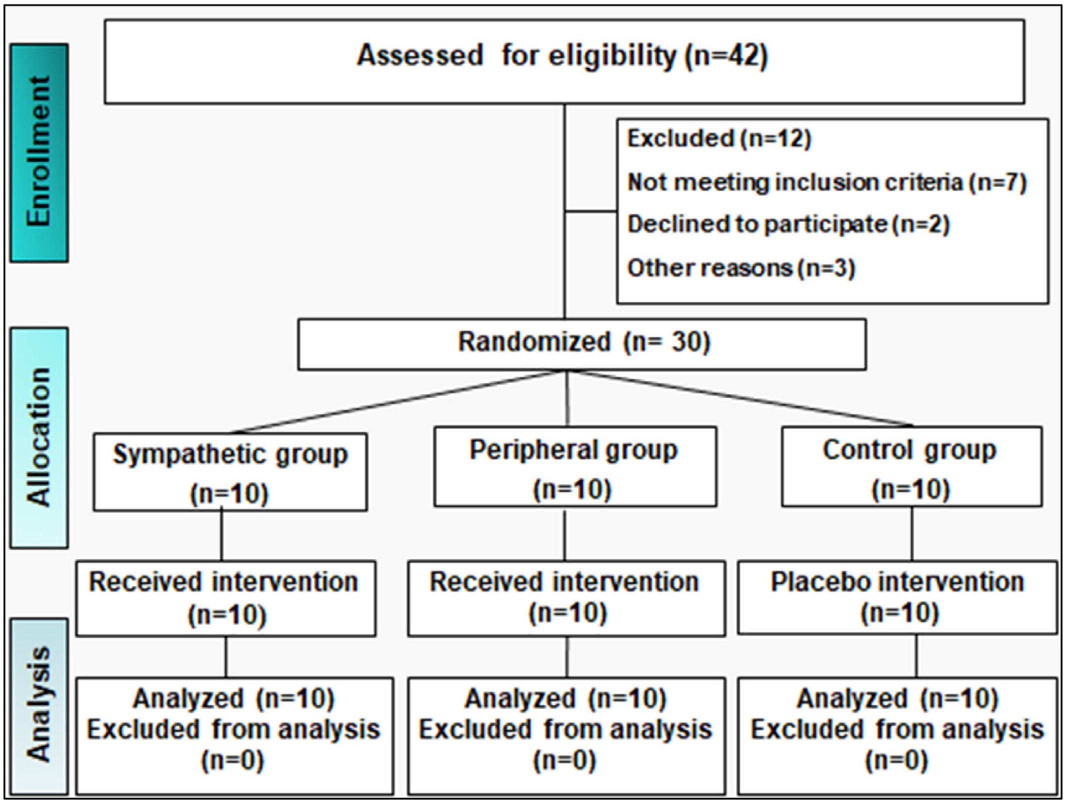

Figure 1: Flow chart of the participants.

Table 1: Participants' characteristics.

		Sympathetic group (n = 10)	Peripheral group (n = 10)	Control group (n = 10)	F value	p value
Age (years)		9.30 ± 1.41	9.70 ± 0.94	9.90 ± 1.44	0.559	0.578
Weight (kilogram)		30.10 ± 6.47	31.70 ± 5.86	32.90 ± 5.89	0.533	0.593
Height (centimeter)		131.20 ± 8.82	133.40 ± 7.91	134.10 ± 7.62	0.346	0.711
Sex (n)	Boy	5	5	6	$\chi^2 = 0.268$	0.875
	Girl	5	5	4		
Spasticity grade (n)	1	7	8	5	$\chi^2 = 2.200$	0.699
	1^+	2	1	3		
	2	1	1	2		
GMFCS level (n)	I	7	7	6	$\chi^2 = 0.300$	0.861
	II	3	3	4		

Data are presented as the mean ± standard deviation or number (n); χ^2 = chi-square test; GMFCS: Gross Motor Function Classification System; significance level at $P < 0.05$.

Table 2: Changes in blood volume pulse amplitude (mV) within and among groups at the three time points.

Groups	Time				
	Blood volume pulse amplitude (mV)				
	Before stimulation	Immediately after	15 min after	F value	P value
Sympathetic group (n = 10)	15.62 ± 4.80	19.50 ± 7.46	16.06 ± 3.80	9.766	0.001*
Peripheral group (n = 10)	16.24 ± 2.84	20.81 ± 3.18	18.23 ± 3.30	17.544	0.0001*
Control group (n = 10)	14.08 ± 4.34	14.07 ± 4.54	14.02 ± 4.46	0.005	0.995
F value	0.740	4.425	2.933		
p value	0.487	0.022 *	0.070		

Data are represented as the mean ± standard deviation, $^*P < 0.05$.

Table 3: Pairwise comparisons within and between groups.

Groups	Time			Time	Group		
	Difference within groups				Difference between groups		
	Immediately after vs Before	15 min after vs Before	Immediately vs 15 min after		Sympathetic vs Peripheral	Sympathetic vs Control	Peripheral vs Control
Sympathetic group	0.0001*	1	0.005*	Before stimulation	1	1	0.744
MD (% change)	3.87 (24.77%)	0.43 (2.75%)	3.43 (17.58%)	MD (% change)	−0.61 (3.90%)	1.54 (10.93%)	2.15 (15.26%)
Peripheral group	0.0001*	0.005*	0.043*	Immediately after	1	0.096	0.028*
MD (% change)	4.56 (28.07%)	1.99 (12.25%)	2.57 (12.34%)	MD (% change)	−1.31 (6.71%)	5.42 (38.52%)	6.73 (47.83%)
Control group	1	1	1	15 min after	0.665	0.756	0.067
MD (% change)	−0.01 (0.07%)	−0.05 (0.35%)	0.04 (0.88%)	MD (% change)	−2.17 (13.51%)	2.03 (14.47%)	4.20 (29.95%)

MD: Mean difference, vs: versus, $^{*}P < 0.05$.

Also, there were significant differences among time of measurements in the sympathetic and peripheral groups.

As shown in Table 3, pairwise comparisons of measurement time indicated a statistically significant increase in BVP amplitude immediately after electrical stimulation session compared with before stimulation for both the sympathetic and peripheral groups with a higher percent change for the peripheral group (28.07%). While there was no statistically significant difference in BVP amplitude before and 15 min after electrical stimulation in the sympathetic group, there was a statistically significant change in the peripheral group that indicated a longer effect of peripheral stimulation than in the sympathetic group. Between-group comparisons showed a statistically significant increase in BVP amplitude immediately after electrical stimulation in the peripheral group compared with the control group with a high percent change (47.83%). Although the percent change of BVP amplitude in the sympathetic group compared with the control group immediately after electrical stimulation was relatively high (38.52%), it was considered statistically nonsignificant ($P > 0.05$). Also, there were statistically nonsignificant differences between the sympathetic and peripheral groups at the three measured time points ($P > 0.05$) (Table 3).

Discussion

This study evaluated the vasomotor effects of two different applications of IFC stimulation on peripheral BF and determined the best application for children with hemiplegic CP. The results revealed that the BVP amplitude increased immediately after application of IFC either through direct sympathetic stimulation or peripheral stimulation with no statistically significant difference between the two applications.

There are continuous sympathetic impulses to the smooth muscles of arterioles, even during rest, leading to a partial continuous degree of vasoconstriction "'sympathetic tone." Its effects include vasoconstriction of the skin and visceral blood vessels and vasodilatation of the coronary vessels. The skeletal muscles receive both noradrenergic and cholinergic sympathetic nerve fibers. The cholinergic sympathetic nerve fibers cause vasodilatation during muscular exercises, which increase blood supply to the muscle and accelerates chemical reactions, leading to proper contraction, delayed fatigue, and early recovery from fatigue.[26,27]

Muscle spasticity in hemiplegic children is accompanied by a decrease in peripheral blood supply and lower limb perfusion due to increased sympathetic vasomotor tone resulting from dysfunction of specific locations in the brain that lead to increased vasoconstriction and restricted cutaneous blood supply. This opinion was supported by Dhindsa et al.[10] and Svedberg et al.,[7] who observed that the damage to certain neural circuits in children with cerebral injury and significant motor defect were the possible causes of the decreased skin temperature observed in these children.

IFC was used as a treatment modality in this study as it has great effects on improving circulation and thus enhancing BF in children with CP. Suh et al.[28] found that IFC has many advantages when used on spastic muscle as it can reduce spasticity, decrease pain and spasm by causing muscle relaxation, and improve circulation by decreasing sympathetic tone and improving the vasomotor effect.

Descriptive statistical analyses for comparisons of mean age, weight, and height among the three groups revealed no statistical difference. Statistical analyses of the median values of GMFCS and spasticity grade distribution of the groups revealed no statistical difference, which support sample homogeneity among the three groups.

The results of this study showed that BVP amplitude was affected by the time intervals among the tested groups. Comparisons within groups revealed immediate significant improvement in BVP amplitude among the three time intervals in the sympathetic study group. This finding was confirmed by Jin et al.,[14] who showed that the application of low intensity with high-frequency sensory stimulation elevated the BF velocity as vessel size increased. The authors also demonstrated that IFC induced the sympathetic tone to block vasoconstriction fibers, which hindered nerve activity and lessened tone in the arterial muscles, thereby improving the circulation.

Santos et al.[16] showed that IFC significantly lowered vasoconstrictor tone, which was observed even when blood pressure increased during the hand function exercises, and significantly moderated muscle metaboreflex activity, indicating that interferential electrical stimulation might have an immediate calming effect on the sympathetic nervous system.

The sympathetic group had a significant increase in BVP amplitude immediately after stimulation versus before application ($P = 0.0001$) and immediately versus 15 min after stimulation ($P = 0.005$), while the mean difference between before and 15 min after stimulation revealed no significant increase in BVP amplitude ($P = 1$). Accordingly, Okudera et al.[29] reported that the mechanism of action underlying the physiological hindering of sympathetic fibers to small arterioles by introduction of high-frequency currents is temporal, and the increase in circulation can be induced by the inhibition of nerve activity, which occurs as a result of the taking away sympathetic tone in the muscular cover of tiny arterioles.

Moreover, Noble et al.[17] demonstrated that, interferential therapy delivered by suction electrodes led to an increase in cutaneous BF, which was accompanied by a rise of superficial body temperature. Their observations showed that the primary biological result is vasodilation, which is caused by IFC suppression of the sympathetic nervous system.

The peripheral study group had a significant increase in BVP amplitude immediately after stimulation compared with before application ($P = 0.0001$) and 15 min afterwards ($P = 0.043$), which supported the effect of IFC peripheral stimulation on peripheral circulation. These results were in accordance with the study by Lamb and Mani,[30] which used both ultrasound and laser Doppler flowmeter together with contemporaneous oxygen tension measurements to examine the influence of different IFC frequencies (0, 30, 45, 90, and 100, 150 Hz) on arterial BF. Interferential therapy was administered for 15 min using four rubber electrodes placed in the upper portion of the calf for the tibial artery and nerve. During, shortly afterwards, and 7 min after interferential therapy, arterial BF markedly increased according to the findings.

The peripheral study group showed a longer positive effect of IFC peripheral stimulation on BVP and enhancement of peripheral circulation, in line with Berglisen et al.[31] who discovered that using a submaximal dose of IFC reduced arterial blood velocity. Their findings led them to hypothesize that the observed effects were caused by blood redistribution between the arterial and microcirculation.

In another study, it was discovered that a frequency of 100 Hz resulted in a significant increase of skin BF. This finding indicated that this frequency has the highest impact on cutaneous BF, which might have consequences in treating peripheral vascular disorders using IFC.[32]

The study results concerned with the comparisons of mean values of BVP amplitude between groups showed a statistically significant increase in BVP amplitude of the peripheral group compared with the control group immediately after stimulation, while a nonsignificant increase in BVP amplitude was found in the sympathetic group compared with the control group at the same time interval. These findings disagree with studies in healthy subjects by Park and Hwang[32] and Kamali et al.,[33] which revealed that electrical stimulation clearly increased peripheral blood circulation but activating the sympathetic ganglion region had a significant effect than directly stimulating the muscle area.

In this study, comparisons of the mean values of BVP amplitude at the three time intervals between the peripheral and sympathetic groups showed a statistically nonsignificant difference, demonstrating that both peripheral and sympathetic IFC stimulation increased BVP amplitude and improved the peripheral circulation within groups, with no significant advantage to any application over the other whether or not peripheral or sympathetic IFC stimulation was used.

This finding was supported by Nussbaum et al.[34] who observed that IFC at different frequencies and electrode locations promoted vasodilation by direct impacts at the cellular level more than through the vasodilatory mechanism.

According to Hurley et al.,[35] IFC with a frequency of 100 Hz is indicated for the decrease of acute edema since such activation will activate the muscular pump and reduce sympathetic activity, hence facilitating the outflow of fluid from the edematous region.

From the present study findings, it was clarified that the right use of electrical current stimulation under a variety of settings is a highly important application in the field of physical rehabilitation. This research is a foundational study that investigated the effect of IFC in improving peripheral blood supply and determined the best application when there is a discrepancy in ANS in children with spastic hemiplegia. The current study is valuable, because it showed that the changes in ANS induced by IFC can lead to better outcome. Thus, our findings may function as fundamental measures of progress in the ANS based on sophisticated applications of electrical stimulation.

Study limitation

For some of the participating children, the measurement took a long time, as they did not follow the instructions given to create a stable hemodynamic state. Some of the children did not avoid food intake at least 1 h before starting the measurement; others did not maintain a relaxed position or avoid unnecessary movements during measurement that can alter BF. Another limitation was that the effects of IFC application on muscle function, spasticity, and quality of life were not determined, which should be assessed in future studies.

Conclusions

The results of this study showed that both IFC direct sympathetic stimulation and peripheral stimulation had useful and important therapeutic effects on improving cutaneous BF in children with spastic hemiplegic CP, with no statistically significant difference between the two applications.

Recommendation

It is necessary to conduct additional clinical investigations to determine the long-term effects of interferential stimulation on BF in children with other types of CP and any neurological disorder characterized by disturbances in the autonomic system and BF restriction. Further studies are needed to study the impact of IFC on spasticity, muscle function, and quality of life.

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Conflict of interest

The authors have no conflict of interest to declare.

Ethical approval

The Ethical Committee of the Faculty of Physical Therapy, Cairo University, Egypt (No: P.T.REC/012/002754) approved this study on June 24, 2020. Children's participation was authorized by a signed written consent form with a parent or legal guardian's agreement before the study was initiated.

Authors contributions

NEM, AAH, and DAMS were involved in the formulation of ideas, selection procedure, and study design. AAH provided the research material, the clinical application of the procedure gathered, and the organized data. NEM, AAH, and DAMS wrote the initial and final drafts of the paper. NEM and DAMS carried out the analyses and interpretation of the data. All authors have critically reviewed and approved the final draft and are responsible for the content and similarity index of the manuscript.

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