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Assessing the Therapeutic Impact of Virtual Reality Interventions on Upper Limb Range of Motion and Functional Mobility in Pediatric Patients with Spastic Hemiplegic Cerebral Palsy: A Faisalabad-based Study

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ABSTRACT

Cerebral palsy is a non-progressive central nervous system injury, most common in children, resulting from the damage to brain. **Objectives:** To see the effects of non-immersive virtual reality on range of motion, muscle strength, spasticity and functional mobility of upper limb in spastic hemiplegic cerebral palsy children. **Methods:** This was a quasi-experimental study, in which participants were selected through simple random sampling on the basis of defined selection criteria, there were two groups. Group A received conventional physical therapy exercises and group B was a received functional mobility exercises using non-immersive virtual reality. Data collection tools included Modified Ashworth scale to measure the spasticity, Functional assessment scale for functional status, Goniometer was used to measure the rage of mobility and Manual muscle testing MMT was used to measure the strength. Data was analyzed by SPSS version 26. **Results:** Mean age of children was 9.818 ± 2.639. From total participants 63.6% were males and 36.4% were females CP child. Paired-t test sowed that, there was a statistically significant difference in means of all outcome measures before and after treatment in group-A as well as in group-B (p-value<0.05). Between-group analysis of A and B showed a statistically significant difference with p-value ≤0.05. **Conclusions:** Both groups showed improvement in spasticity, functional status, range of motion and muscle strength, but treatment group receiving functional mobility exercises using non-immersive virtual reality was found to be more effective than the control group.

INTRODUCTION

Cerebral palsy (CP) is defined as a group of disorders, which causes permanent damage to the movement and posture during the developing phase (neonatal phase) [1]. Cerebral palsy is an umbrella term that was first introduced by orthopedic surgeon William little in 1861. It is defined as the abnormalities in the developing brain of the neonatal which ultimately results in musculoskeletal flaws and deformations, including postural oddities and neurological deficits [2, 3]. Cerebral palsy is the most common dysfunction in children with the occurrence of 2.1 per 1000 births in advanced countries, even though the rate of prevalence is greater in underprivileged countries [4]. The cost related to the life span of CP children is very high. It is also very difficult for the attendants of the patient to provide adequate treatment to the children because of the high expenses of the treatment. Extra life span expense is

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estimated to be 800000 US$ for one person [5]. The clinical manifestation of Cerebral palsy includes spasticity (muscular stiffness that prevents normal movements), dyskinesis (unconstrained reflexive movement comprises of chorea, athetosis, dystonia), Ataxia (loss of coordination), and hyperreflexia (exaggerated reflexes). These undesired movements are due to pathological ailments in the brain and cerebral cortex. Ataxia is caused by damage to the cerebellum which involves gait disturbances (drunken gait). Chorea incorporates sudden jerky movements of the muscles of arms, legs, and face [4]. The treatment of Cerebral palsy comprises Medical as well as physiotherapy treatments. Medical treatment includes the use of various drugs to decrease spasticity and orthopedic surgical procedures to enhance joint appropriateness and neurological surgical methods to improve nerve conduction while physical therapy-related interventions incorporate many exercises and therapies to enhance functional independence, to improve muscular integrity, to reduce contractures, to improve the quality of life and to ease activities of daily living (ADL's) [6]. The therapeutic way of treatment which is very popular and known as neurodevelopmental treatment NDT was used to improve motor functioning in patients with cerebral palsy. It includes developing controlled motor conditions, which discourage conditions that are limiting our natural movements of daily living, and this is done by providing postural adjustments of movements and functional rehabilitation [7, 8]. Virtual reality is not a new concept and was first initiated in Sutherland in 1970 and a model was presented regarding creating a virtual environment and exploiting things realistically. Later on, in 1993, Krueger gave solid references related to virtual reality and immersive technology. During the 1900s, Most Virtual reality applications became required for excitation purposes during training in many fields [9]. In the past years, for location and direction of vision from the head tracker and production of two pictures for three-dimensional images for both eyes, a very high precision position tracking system was needed which use different types of infrared sensors, parallelized computer applications, and high-resolution 3D displays [10]. Virtual reality has shown us an imaginary world and fascinated it to such extent that it is hard to differentiate it from the real world. It plays with the minds of the people and it is the man-made condition [11]. Virtual reality has been widely used in the field of medicine for example, in the practicing of a surgery, to treat anxiety, depression, phobias and pain, to deal with disability and therapeutic rehabilitation [12]. Virtual reality has a vast role in Medical and healthcare systems. It used in psychological therapy, medical rehabilitation, physical therapy, medical scientific research, and educational training for patients, students, and doctors. By using virtual reality, doctors as well as students can interconnect with the human body and can be used for instructional and training purposes with the use of Virtual reality headsets and stereoscopic pictures [13]. Motor re-learning programs is incorporated with virtual reality in rehabilitation of many neurological conditions. Functional training has been done using virtual reality to make the tasks easier and enjoyable. In senior patients, exercises are done in virtual environments to make them feasible and more effective. People get motivation when they achieve a goal so goal-oriented tasks has been practiced utilizing augmented reality environments. It plays a great role in cognitive rehabilitation of patients dealing with neurological conditions. Virtual reality has great implementation in rehabilitation of upper extremity however we can use it in balance training and gait improvements in lower extremity [14].

The aims and objectives of this study were to check the immediate effect of virtual reality-based rehabilitation on spastic hemiplegic cerebral palsy children. The rationale behind this investigation was to understand the potential benefits and limitations of integrating advanced technology into therapeutic practices for CP children, thereby contributing to more effective treatment strategies. Its significance lies in exploring how such technology influences their functional mobility and upper extremity range of motion, compared to traditional methods without virtual reality. This study filled a critical gap in literature by providing insights into the effects of non-immersive virtual reality as a therapeutic tool for cerebral palsy.

METHODS

It was a quasi-experimental trial. Sample size of the research was 33 which were calculated through open Epitool software. The target population of the study was children with cerebral palsy. Through simple random sampling, subjects were selected and recruited in the study. Study period was 6 months. Participants of both genders having age 6 to 18 years, having sufficient cognitive capacity to understand the basic instructions and spastic hemiplegic cerebral palsy children (SHCP) was included in this trial. Exclusion criteria included epileptic patients, children of age above 18 years, having history of migraines, headaches and flu and totally impaired cognitive capacity and history of any fracture or dislocation. This was a quasi-experimental trial. This study analyzed the effect of virtual reality exercise techniques on participant's pain and disability. Before participation in study, all caregivers of the participants were asked to sign a consent form. Only diagnosed participants were enrolled in study that fulfilled the requirements of inclusion and

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exclusion criteria. Participants between aged 6 to 18 years were selected. 33 participants were selected and categorized them into two groups through the lottery method. One group received conventional physical therapy and other group received virtual reality therapy. Pre evaluation was done and then participants received a session of intervention. A total of three sessions were given in a week with alternative days applying both conventional and virtual therapy techniques. After three sessions, a post treatment values were taken. Data collection tools included Modified Ashworth scale to measure the spasticity, Functional assessment scale for functional status, universal goniometer was used to measure the rage of mobility and Manual muscle testing MMT was used to measure the strength. The statistical analysis was done using version-26.0 of SPSS. Shapiro-Wilk test was used to understand that data was normally distributed or not. Modified Ashworth Scale, Functional assessment scale, Manual muscle testing and Wrist and forearm ROM at baseline show p-value more than 0.05 which indicate that data was normally distributed and parametric test (Independent sample T-test for between group assessment and Paired Sample T test for within group assessment) was applied. Data was presented in form of tables and graphs. The study received institutional approval from "Government college university Faisalabad. Informed consent forms were signed were guardians of the patients prior to collect the data. Privacy of all subjects was prioritized.

RESULTS

Figure 1 shows the frequency distribution of gender in which 21 (63.6%) male and 12 (36.4%) female CP child were included.

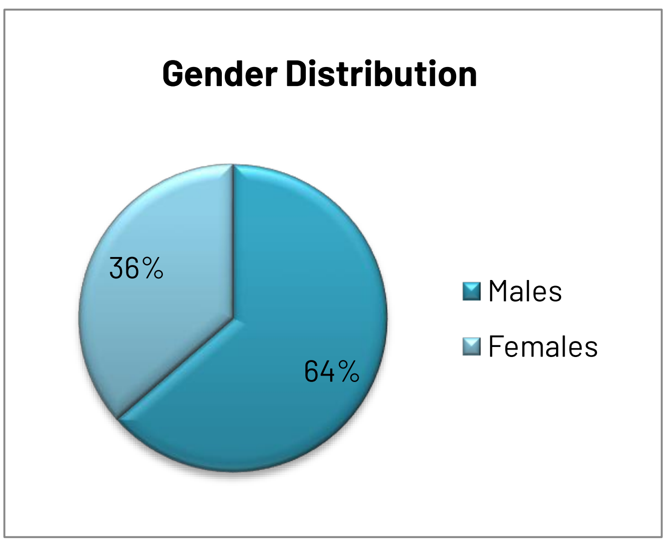

Figure 1: Gender distribution of CP children

Figure 2 shows the age of the CP child in which N=33 with mean 9.818 and standard deviation 2.639.

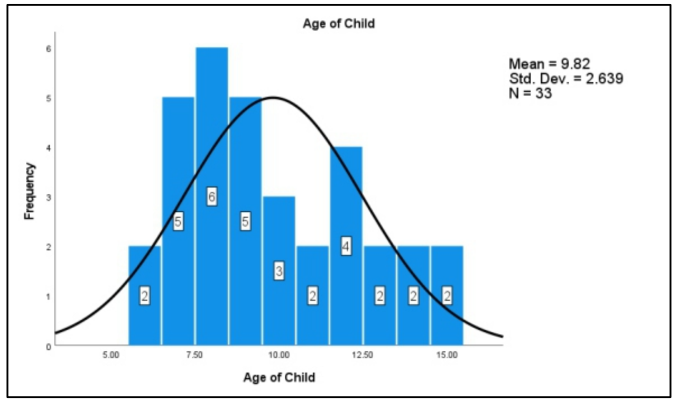

Figure 2: Age distribution of the CP children

For within-group difference Paired Sample T-Test was applied (Table 1 and 2). Paired difference of Modified Ashworth Scale in Group A was 1.250 ± 1.00 with significant p-value <.001 and paired difference in group B was 1.117 ±.781 with significant p-value <.001. Paired difference of Functional Assessment Scale in Group A was 10.062 ± 7.352 with significant p-value <.001 and paired difference in group B was 3.176 ± 3.521 with significant p-value 0.002. Paired difference of Manual Muscala Testing in Group A was 1.117 ±.704 with significant p-value <.001 and paired difference in group B was 0.235 ± 0.562 with non-significant p-value 0.104. Paired difference of wrist flexion in Group A was 16.562 ± 5.977 with significant p-value <.001 and paired difference in group B was 9.705 ± 4.831 with significant p-value <.001. Paired difference of wrist extension in Group A was 14.687 ± 9.213 with significant p-value <.001 and paired difference in group B was 6.176 ± 5.736 with significant p-value <.001. Paired difference of Ulnar deviation in Group A was 5.812 ± 3.166 with significant p-value <.001 and paired difference in group B was 2.823 ± 1.424 with significant p-value <.001. Paired difference of Radial deviation in Group A was 8.562 ± 5.921 with significant p-value <.001 and paired difference in group B was 5.000 ± 7.905 with significant p-value 0.019. Paired difference of supination in Group A was 5.000 ± 5.773 with significant p-value 0.003 and paired difference in group B was 2.058 ± 8.849 with significant p-value 0.035. Paired difference of pronation in Group A was 3.375 ± 7.588 with significant p-value 0.019 and paired difference in group B was 2.352 ± 8.681 with significant p-value 0.028.

Table 1: Group A Within group analysis (Paired T-test)

Group		N	Mean ± SD	Asymp. Sig.
Group A	MAS Baseline	16	3.125±1.147	<0.001
	MAS After Treatment	16	1.875±1.258	
Group A	FAS Baseline	16	51.500±7.302	<0.001
	FAS After Treatment	16	61.562±6.762	
Group A	MMT Baseline	16	2.250±.856	<0.001
	MMT After Treatment	16	3.937±.853	

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Group A	Wrist Flexion Baseline	16	37.500±7.302	**<0.001**
	Wrist Flexion After Treatment	16	54.062±7.352	
Group A	Wrist Extension Baseline	16	37.812±6.046	**<0.001**
	Wrist Extension After Treatment	16	52.500±10.165	
Group A	Ulnar Deviation Baseline	16	7.937±1.181	**<0.001**
	Ulnar Deviation After Treatment	16	13.750±3.276	
Group A	Radial Deviation Baseline	16	29.875±3.500	**<0.001**
	Radial Deviation After Treatment	16	38.437±3.966	
Group A	Supination Baseline	16	37.187±7.295	**0.003**
	Supination After Treatment	16	42.187±3.637	
Group A	Pronation Baseline	16	38.437±7.238	**0.019**
	Pronation After Treatment	16	41.812±3.902	

Table 2: Group B Within group analysis (Paired T-test)

Group		N	Mean ± SD	Asymp. Sig.
Group B	MAS Baseline	17	3.823±1.131	**<0.001**
	MAS After Treatment	17	2.705±.985	
Group B	FAS Baseline	17	53.117±8.146	**0.002**
	FAS After Treatment	17	56.294±6.917	
Group B	MMT Baseline	17	2.882±1.166	**<0.001**
	MMT After Treatment	17	3.117±1.111	
Group B	Wrist Flexion Baseline	17	39.117±8.146	**<0.001**
	Wrist Flexion After Treatment	17	48.823±6.257	
Group B	Wrist Extension Baseline	17	39.411±8.078	**<0.001**
	Wrist Extension After Treatment	17	45.588±8.269	
Group B	Ulnar Deviation Baseline	17	8.647±1.114	**<0.001**
	Ulnar Deviation After Treatment	17	11.470±1.736	
Group B	Radial Deviation Baseline	17	29.705±3.293	**0.019**
	Radial Deviation After Treatment	17	34.705±5.987	
Group B	Supination Baseline	17	40.294±9.596	**0.035**
	Supination After Treatment	17	38.23±5.847	
Group B	Pronation Baseline	17	40.294±9.596	**0.028**
	Pronation After Treatment	17	37.941±5.606	

Table 3 and table 4 shows the between-groups comparison before and after the treatment. Independent sample t test in table 3 shows that there was no statistically significant difference between group A and before the treatment ($p>0.05$). A statistically significant difference was observed in all outcomes between group A and B after the treatment ($p<0.05$) (Table 4).

Table 3: Between group analysis before treatment (Independent sample T-test)

Group		Mean ± SD	N	T	Asymp. Sig.
Group A	MAS Before Treatment	3.125±1.147	16	-1.761	.088
Group B	MAS Before Treatment	3.823±1.131	17		
Group A	FAS Before Treatment	51.500±7.302	16	-.599	.553
Group B	FAS Before Treatment	53.117±8.146	17		
Group A	MMT Before Treatment	2.250±.856	16	-1.766	.087
Group B	MMT Before Treatment	2.882±1.166	17		
Group A	Wrist Flexion Before Treatment	37.500±7.302	16	-.599	.553
Group B	Wrist Flexion Before Treatment	39.117±8.146	17		
Group A	Wrist Extension Before Treatment	37.812±6.046	16	-.641	.526
Group B	Wrist Extension Before Treatment	39.411±8.078	17		
Group A	Ulnar Deviation Before Treatment	7.937±1.181	16	-1.775	.086
Group B	Ulnar Deviation Before Treatment	8.647±1.114	17		
Group A	Radial Deviation Before Treatment	29.875±3.500	16	.143	.887
Group B	Radial Deviation Before Treatment	29.705±3.293	17		
Group A	Supination Before Treatment	37.187±7.295	16	-1.042	.306
Group B	Supination Before Treatment	40.294±9.596	17		
Group A	Pronation Before Treatment	38.437±7.238	16	-.624	.537
Group B	Pronation Before Treatment	40.294±9.596	17		

Table 4: Between group analysis after treatment (Independent sample T-test)

Group		Mean ± SD	N	t	Asymp. Sig.
Group A	MAS After Treatment	1.875±1.258	16	-2.119	.042
Group B	MAS After Treatment	2.705±.985	17		
Group A	FAS After Treatment	61.562±6.762	16	2.210	.035
Group B	FAS After Treatment	56.294±6.917	17		
Group A	MMT After Treatment	3.937±.853	16	2.365	.024
Group B	MMT After Treatment	3.117±1.111	17		
Group A	Wrist Flexion After Treatment	54.062±7.352	16	2.209	.035
Group B	Wrist Flexion After Treatment	48.823±6.257	17		
Group A	Wrist Extension After Treatment	52.500±10.165	16	2.149	.040
Group B	Wrist Extension After Treatment	45.588±8.269	17		
Group A	Ulnar Deviation After Treatment	13.750±3.276	16	2.519	.017
Group B	Ulnar Deviation After Treatment	11.470±1.736	17		
Group A	Radial Deviation After Treatment	38.437±3.966	16	2.097	.044
Group B	Radial Deviation After Treatment	34.705±5.987	17		
Group A	Supination After Treatment	42.187±3.637	16	2.314	.027
Group B	Supination After Treatment	38.235±5.847	17		
Group A	Pronation After Treatment	41.812±3.902	16	2.288	.029
Group B	Pronation After Treatment	37.941±5.606	17		

DISCUSSION

Cerebral palsy is a non-progressive central nervous system injury, most common in children, resulting from the damage to brain. The purpose of the present study was to analyze the effects of non-immersive virtual reality on range of motion, muscle strength, spasticity and functional mobility of upper limb in spastic hemiplegic cerebral palsy children. Because Spastic Hemiplegic Cerebral Palsy (SHCP) is the most prevalent type among types of Cerebral palsy which is caused by one-sided damage to the motor cortex or pyramidal pathway, that why children of spastic

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cerebral palsy were selected in the study [15]. In present study, percentage of the CP children (N=33) was 9.818±2.639. From total participants 63.6% were males and 36.4% were females CP child. Paired-t test sowed that, there was a statistically significant difference in means of all outcome measures before and after treatment in group-A as well as in group-B (p-value<0.05). Between-group analysis of A and B showed a statistically significant difference with p-value ≤0.05. Results of the present study revealed that although both treatment and control groups showed improvement in spasticity, functional status, range of motion and muscle strength, but treatment group receiving functional mobility exercises using non-immersive virtual reality was found to be more effective than the control group in all outcome measures. In support with these results, Adams et al., reported that virtual reality approach are very beneficial as compared to conventional neurophysiological treatments as they have more realistic approach towards environment, participant feels more comfortable and enjoyable as the environment is relaxing as compared to typical clinical one even patient forgets that he is under treatment and ultimately shows a noticeably good participation and overall his learning capability enhanced to a large extent [16]. In present study, by performing functional mobility exercises using non-immersive virtual reality in spastic CP, improvements in functional status, spasticity, muscle strength and upper extremity range of motion was found. The same findings were reported by Todorov et al., that improvements in functional abilities, speed of gait as well as balance of functions and movements have been found following VR training [17]. Moreover, VR has also been proved useful to train and enhance motor learning of cerebral palsy children [18]. Previous literature reported that, virtual reality therapy showed significant gain in motor skills by increasing cortical reorganization and neoplastic changes in a very young child of eight years old [19]. Findings of a study by Williams et al., revealed that total motor functions and total independence in daily lives in both control and treatment groups improved after 8 weeks of intervention. A comparison between groups revealed significantly greater improvements in both gross and fine motor functions and daily activities in the VR group than in the TOT group (P < 0.001) [20]. Similar outcomes were found by the present study.

CONCLUSIONS

Several inferences about the prevalence of musculoskeletal pain among badminton players can be made based on the findings. The results of this study showed that beginners players are more likely to have musculoskeletal pain. The most often affected body parts among badminton players were the shoulder and knee.

Authors Contribution

Conceptualization: AK
Methodology: AJ
Formal analysis: AI
Writing-review and editing: TG, NK, SKK, MB
All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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REFERENCES

[1] Sperotto F, Balzarin M, Parolin M, Monteforte N, Vittadello F, Zulian F. Joint hypermobility, growing pains and obesity are mutually exclusive as causes of musculoskeletal pain in school children. Paediatric Rheumatology. 2013 Jan; 32: 131-6.

[2] Arora M, Shetty SH, Khedekar RG, Kale S. Over half of badminton players suffer from shoulder pain: is impingement to blame? Journal of Arthroscopy and Joint Surgery. 2015 Jan; 2(1): 33-6. doi: 10.1016/j.jajs.2014.12.006.

[3] Paup D. Skills, drills & strategies for badminton: Taylor & Francis; 2017. doi: 10.4324/9781315212951.

[4] Marchena-Rodriguez A, Gijon-Nogueron G, Cabello-Manrique D, Ortega-Avila AB. Incidence of injuries among amateur badminton players: A cross-sectional study. Medicine. 2020 May; 99(18): e19785. doi: 10.1097/MD.0000000000019785.

[5] Guermont H, Le Van P, Marcelli C, Reboursière E, Drigny J. Epidemiology of injuries in elite badminton players: a prospective study. Clinical Journal of Sport Medicine. 2021 Nov; 31(6): e473-e5. doi: 10.1097/JSM.0000000000000848.

[6] Muttalib A, Zaidi M, Khoo C. A survey on common injuries in recreational badminton players. Malaysian Orthopaedic Journal. 2009 Nov; 3(2): 8-11. doi: 10.5704/MOJ.0911.002.

[7] Docking SI, Rio E, Cook J, Orchard JW, Fortington LV. The prevalence of Achilles and patellar tendon injuries in Australian football players beyond a time-loss definition. Scandinavian Journal of Medicine and Science in Sports. 2018 Sep; 28(9): 2016-22. doi: 10.1111/sms.13086.

[8] Pardiwala DN, Subbiah K, Rao N, Modi R. Badminton injuries in elite athletes: a review of epidemiology and biomechanics. Indian Journal of Orthopaedics. 2020 May; 54(3): 237-45. doi: 10.1007/s43465-020-00054-1.

DOI: https://doi.org/10.54393/tt.v4i04.178

[9] Jørgensen U and Winge S. Epidemiology of badminton injuries. International Journal of Sports Medicine. 1987 Dec; 8(06): 379-82. doi: 10.1055/s-2008-1025689.
[10] Krøner K, Schmidt S, Nielsen A, Yde J, Jakobsen B, Møller-Madsen B, et al. Badminton injuries. British Journal of Sports Medicine. 1990 Sep; 24(3): 169-72. doi: 10.1136/bjsm.24.3.169.
[11] Huang MT, Lee HH, Lin CF, Tsai YJ, Liao JC. How does knee pain affect trunk and knee motion during badminton forehand lunges? Journal of Sports Sciences. 2014 Apr; 32(7): 690-700. doi: 10.1080/02640414.2013.848998.
[12] Yung PS, Chan RH, Wong FC, Cheuk PW, Fong DT. Epidemiology of injuries in Hong Kong elite badminton athletes. Research in Sports Medicine. 2007 Jun; 15(2): 133-46. doi: 10.1080/15438620701405263.
[13] Reeves J, Hume PA, Gianotti S, Wilson B, Ikeda E. A retrospective review from 2006 to 2011 of lower extremity injuries in badminton in New Zealand. Sports. 2015 Jun; 3(2): 77-86. doi: 10.3390/sports3020077.
[14] Palmer K, Smith G, Kellingray S, Cooper C. Repeatability and validity of an upper limb and neck discomfort questionnaire: the utility of the standardized Nordic questionnaire. Occupational Medicine. 1999 Apr; 49(3): 171-5. doi: 10.1093/occmed/49.3.171.
[15] Araújo CG and Scharhag J. Athlete: a working definition for medical and health sciences research. Scandinavian Journal of Medicine and Science in Sports. 2016 Jan; 26(1): 4-7. doi: 10.1111/sms.12632.
[16] de Oliveira VM, Pitangui AC, Gomes MR, da Silva HA, Dos Passos MH, de Araújo RC. Shoulder pain in adolescent athletes: prevalence, associated factors and its influence on upper limb function. Brazilian Journal of Physical Therapy. 2017 Mar; 1(2): 107-13. doi: 10.1016/j.bjpt.2017.03.005.
[17] Fahlström M, Yeap JS, Alfredson H, Söderman K. Shoulder pain–a common problem in world-class badminton players. Scandinavian Journal of Medicine and Science in Sports. 2006 Jun; 16(3): 168-73. doi: 10.1111/j.1600-0838.2004.00427.x.
[18] Senadheera VV. Epidemiological review of badminton related injuries among competitive badminton players. International Journal of Sports Science and Physical Education. 2019 Nov; 4(3): 41-4. doi: 10.11648/j.ijsspe.20190403.12.
[19] Noormohammadpour P, Rostami M, Mansournia MA, Farahbakhsh F, Pourgharib Shahi MH, Kordi R. Low back pain status of female university students in relation to different sport activities. European Spine Journal. 2016 Apr; 25: 1196-203. doi: 10.1007/s00586-015-4034-7.
[20] Ullah I, Marwat NM, Sadiq A, Mughal EA, Virk IA, Nazir S. Risk factors of knee pain; prevalence in athletes. PalArch's Journal of Archaeology of Egypt/Egyptology. 2021 Mar; 18(2): 973-82.