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BALANCE IMPAIRMENT IN CHILDREN WITH CHRONIC KIDNEY DISEASES

(A CROSS SECTIONAL STUDY)

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ABSTRACT

Background: Chronic kidney disease is associated with comorbid conditions that result in balance impairments. **Purpose:** Investigate balance impairments in children with CKD compared with age matched typically developing children. **Subjects and methods:** A total of 75 children, age ranged from 8 to 15 represented three groups of equal numbers; control group (typically developed), non-dialysis (stage 2 through 4) and hemodialysis group. Balance was assessed by the Human Assessment Computer (HUMAC) Balance System. **Results:** Compared with typically developed children, children with CKD showed a statistically significant low stability scores ($P<0.05$). Those on-hemodialysis showed significant impairments compared with non-dialysis group. **Conclusion:** Children with CKD exhibit balance impairments regardless the cause and duration of the disease.

Key Words: Balance, Chronic kidney disease, HUMAC balance system.

INTRODUCTION

Postural stability either static or dynamic is achieved by complex integration between neuromusculoskeletal structures which convey sensory inputs i.e. somatosensory, proprioceptive and visual information. Sensory information processing contributes to the proper motor output necessary for postural adjustment **(Zanotto et al., 2017; Leach et al., 2018; Wilkinson et al., 2019)**. Postural sway is one of the most fundamental positions that maintain static postural stability and is known as the ability to keep the center of pressure (COP) in a fairly constant position within the boundaries of the base of support (BOS) **(Razavi, 2017)**.

Hereditary and acquired neuromusculoskeltal pathologies interfere with the development of postural stability and can lead to balance disorders. Chronic kidney disease (CKD) is a life threatening silent killer pathology affecting adults and children **(Yeung et al., 2014; Schijvens et al., 2019)**. It is irreversible slow progressive disease that induces loss of renal function. In pediatric population, congenital diseases and glomerular disorders are the prim causes of CKD with overall prevalence of 55 to 75 per million **(Pardede et al., 2020)**. The diagnostic criteria of CKD are: 1) structural or functional abnormalities (Kidney damage) for ≥ three months, with/without low glomerular filtration rate (GFR), 2) GFR < 60 mL/min/1.73 m^2 for ≥ three months, with/without kidney damage **(Sreedharan and Avner, 2016; Schnaper, 2016)**. CKD is classified into five categories based on GFR according to Schwartz formula. Stage 1 indicates renal failure, stages 2 through 4 indicate mild to severe kidney damage, while stage five represents end stage renal disease (ESRD) **(Schwartz et al., 2009; Howden et al., 2013)**.

Evidence shows that individuals with CKD exhibit physical inactivity, poor exercise capacity, reduced quality of life, lower postural stability in addition to mental, and social impairments compared to healthy individuals **(Wilhelm-Leen et al., 2009; MacKinnon et al., 2018; Wilkinson et al., 2019)**. Impairments of stability are attributed to muscle weakness that reduces proprioception efficiency **(MacKinnon et al., 2018)**. Deficiencies in physical performance among patients with CKD result from altered muscle activity, a complex interaction in sensory input conversion and motor response **(Kleiner et al., 2011)**.

Several studies investigated postural stability impairments and rehabilitation in non-dialysis adult patients with CKD **(Wilkinson et al., 2019)** and undergoing hemodialysis **(Abedi Yekta et al., 2016; Carletti et al., 2017; Lucinda et al., 2019; Abdelaal and Abdulaziz, 2019).**

Early ascertainment of children with CKD with poor postural stability may grant convenient intervention. Given that postural stability is reduced in adults CKD populations, it appears radical for further consideration into the prevalence of poor postural stability among children with CKD. However, limited evidence is available regarding postural stability in children with CKD. Accordingly, the current study aimed to investigate balance impairments in children with CKD compared with age matched typically developing children. We hypothesized that children with CKD would have significantly lower postural stability than a control reference cohort.

MATERIALS AND METHODS

Study design and ethical consideration

A prospective cross-sectional observational study that evaluated balance impairments in children with CKD was conducted from January 2019 to November 2019 at Nephrology Unit, Zagazig University Hospitals in accordance with the Declaration of Helsinki (Code of Ethics of the World Medical Association). The study protocol was approved by the Ethical committee of the Faculty of Physical Therapy, Cairo University, Egypt (No.P.T.REC/012/002169). Children's participation was authorized by a signed written consent form with parent's/legal guardian's acceptance for participation before starting the study procedures.

Participants

Seventy-five eligible volunteer children with CKD were recruited from Nephrology Unit, Zagazig University Hospitals to be enrolled in this study. Eligible criteria: 1) medically diagnosed with CKD (regardless of medical history), 2) age ranged from eight to fifteen years, 3) both genders. Participants were excluded if they had: 1) communication problems such as intellectual disability, autism, Down syndrome, or cerebral palsy, 2) significant visual or hearing problems, 3) any neurological or musculoskeletal disorder which affected postural control, 4) chronic cardiovascular or pulmonary disorders.

The study included 50 children with CKD allocated into either hemodialysis (on hemodialysis) or non-dialysis group (children at stage 3 and 4) compared to 25 typically developed age matched group.

Study power and sample size

Sample size calculation was estimated prior to the study using G*POWER statistical software (version 3.1.9.2; Franz Faul, Universitat Kiel, Germany) [F tests- ANOVA: Fixed effects, one-way, $\alpha=0.05$, $\beta=0.2$, and large effect size] with the number of groups=3, producing a total number of 66 participants to be enrolled in this study.

Basic demographic and clinical information

Demographic (age, sex, weight, height, body mass index) and clinical (renal function test, recent hematology and blood chemistry counts, co-morbidity, medication) data were recorded from medical records.

Materials for assessment

The Human Assessment Computer (HUMAC) Balance System was used in the current study to assess the limits of stability. HUMAC, primarily being part of a video game appliance (Wii Balance Board), is a distinct technology used in assessment and rehabilitation of postural control. It is an affordable, portable and prevalent obtainable force plate provides the patient and tester with visual feedback as well as numerical data. The system displays several reporting options with objective, informative data to provide clinicians with insights into the patients' progress which is used for baseline and follow-up analysis with eight programs to choose from **(Blosch, et al 2019)**. The HUMAC-type technology has been found to detect more imbalances than traditional tests **(Merchant-Borna et al., 2017).** In the current study limits of stability at level 4 and level 6 were assessed.

Procedures for assessment

Limits of stability are known as the maximum distance a subject is able to move his/her COP in different directions while keeping the configuration of the BOS and while remaining stable. This usually involves the use of a force plate that records COP displacement and a visual display that serves as feedback to maximize COP movement in specific directions **(Lemay et al., 2014)**. During this test the participant is instructed to move the round cursor on the screen (their COP) to the highlighted target. As he/she remains in the target for the hold time, this target point is deactivated and should move between the center targets to each surrounding target in a random order. A count-up timer displays the total test time. He/she must return to the center target after each outer target. The test was conducted at two levels 4 and 6. At level 4, this is considered as simple test compared with level 6, the distance between center targets to each surrounding target is relatively small. On the other hand, at level 6 the distance between center targets to each surrounding target is larger. Each child in the study groups performed three trials and the mean was calculated and recorded.

Data processing and statistical analysis

All statistical measures were performed through the statistical package for social studies (SPSS) version 25 for windows. Descriptive statistics and One-way analysis of variance (ANOVA) was carried out for comparison of subject characteristics between groups and to compare limits of stability at levels 4 and 6 between the study groups. The level of significance for all statistical tests was set at $p < 0.05$.

RESULTS

Table I demonstrates the participants' characteristics of the study groups. There were no statistically significant differences (P>0.05) between participants of the study groups regarding their ages, weights, heights and gender.

Table (I): Participants' characteristics

	Groups				
	Hemodialysis	**Non-dialysis**	**Control**	**f-value**	**p-value**
Age (years)	**10.72±2.42**	**11.68±1.77**	**11.4±3**	**1.01**	**0.36**
Weight (Kilogram)	**34.52±7.58**	**33.72 ± 7.77**	**32.72 ± 5.81**	**0.4**	**0.67**
Height (Centimeter)	**139.72±15.16**	**140.84±14.42**	**138±15.57**	**0.22**	**0.8**
Gender (N/%)					
Girls	**13(52)**	**16(64)**	**17(68)**		**0.48**
Boys	**12(48)**	**9(56)**	**8 (32)**		
Level of significance at p<0.05		***: Significant**			

The comparisons between the groups in respect with the limits of stability scores are demonstrated in table II. Regarding the limits of stability scores at levels 4 and 6 of the study groups was a significant difference in limits of stability at level 4 (p=0.0001). The results showed that, children on-hemodialysis demonstrated lower scores than non-dialysis and controls. However, there was non-significant difference between non-dialysis and controls (p=0.33). While non-significant difference was recorded in the limits of stability scores at levels at level 6 (p = 0.22) (table III).

Table (II): Mean and standard deviation of limits of stability in the study groups

	Groups				
	Hemodialysis	**Non-dialysis**	**Control**	**f-value**	**p-value**
level 4	24.6 ± 5.68	28.72 ± 5.3	30.88 ± 11.08	8.76	0.0001*
level 6	24.88 ± 5.43	25.6 ± 5.11	27.6 ± 6.56	1.5	0.22
Level of significance at p<0.05		***: Significant**			

Table (III): Multiple comparison (Tukey) between groups

	Groups	MD	p- Value
Limits of stability at level 4	**Hemodialysis group – Non-dialysis group**	**-4.12**	**0.02***
	Hemodialysis group – Control group	**-6.28**	**0.0001***
	Non-dialysis group - Control group	**-2.16**	**0.33**

***: Significant** **MD: Mean difference** **P-value: Probability value**

DISCUSSION

The present study endeavored to investigate the balance impairment in children with CKD. Several studies have reported impairments in postural stability in adult patients with CKD. To our knowledge, this is the first empirical report as for measurement of postural stability in this population. The primary findings of the current study were that: (1) children with CKD, on-hemodialysis and non-dialysis, have lower postural stability than a control reference cohort; (2) non-dialysis children have better postural stability than those on-hemodialysis.

Blake et al. (2004) stated that, postural stability was 39% poorer in patients on hemodialysis compared to controls. In the same context **Shin et al. (2014)** have investigated standing postural control performance in adults undergoing hemodialysis. They documented that under static balance conditions, patients undergoing hemodialysis displayed decreased postural stability compared to healthy controls. Similarly, **Wilkinson et al., (2019)** studied the relation between physical and cognitive functions in non-dialysis adults with CKD. The findings of their study suggest that, low physical and cognitive functioning adversely affect postural stability in this patient group.

The results of the current study can be ascribed to the somatosensory, vestibular and cognitive impairments are reported in young adults and elderly with CKD either non-dialysis or on-hemodialysis treatment. In consistence with our results, it has been reported that visual, vestibular and proprioceptive impairments are associated with decreased postural control **(BlakZanotto et al., 2017; Leach et al., 2018).**

The results of the current study come in accordance with **Nusinovici et al. (2018)** who stated that, kidney and eye diseases may be interlinked. They added that optical morbidity in individuals with renal failure is prevalent and patients undergoing dialysis may develop acute ocular problems. They suggested that patients with CKD should undergo frequent complete ocular investigations.

Wong et al. (2014) stated that, patients with CKD are at higher risk for ocular problems as glaucoma and cataract. Furthermore, optical manifestations have been shown to be a predictive parameter of CKD development. In the same context, **Yip et al. (2017)** stated that, retinal microvascular anomalies may indicate renal microvascular abnormalities implicated in the development of CKD.

The children participated in the current study were diagnosed with stage 3 to 5 renal failure. **Deva et al. (2011)** investigated the prevalence of ocular abnormalities in stages 3 to 5 CKD. They concluded that ocular abnormalities are frequent and more intense among patients with CKD stage 3 to 5 than patients in stage 1 and 2.

Further in consistence with our findings, previous studies have shown that patients with CKD have impaired postural stability. These impairments may be related to musculoskeletal changes as muscle atrophy and fragility **(Shin et al., 2014)** that diminishes sensory and proprioceptive capacity **(Zanotto et al., 2017).** Along with musculoskeletal changes and physical deconditioning, balance is related to cognitive processing **(Leach et al., 2018)**. Furthermore, cochlear and vestibular manifestations are common among patients on dialysis (peritoneal and hemodialysis) which may result from immune abnormalities in inner ear **(Klagenberg et al., 2013).**

Our results can be attributed to onset and duration of the disease as well as the duration and frequency of dialysis therapy adversely affect patient's performance. Unlike adults, the onset of the disease and duration of hemodialysis treatment children population among are relatively short. **Klagenberg et al., (2013)** documented that, those received long-term dialysis, are at high risk of ear and vestibular disease.

Postural stability is the product of interaction and integration between multiple systems to modulate sensory information and execute motor response to achieve balance. Patients with renal failure exhibit changes in the peripheral and central nervous system. Patients with chronic renal failure have diminished conduction velocity in the sensory and motor units with the sensory units being more affected than the motor in addition to auditory nerve and pathways dysfunctions **(Thodi et al., 2006).**

Slowing of nerve conduction is a frequent manifestation in patient CKD with no signs of neuropathy. Those with moderate renal failure not requiring dialysis exhibit decreased velocity of motor-nerve conduction. Patients with marked deterioration in kidney functions have significant low conduction velocities **(Krishnan and Kiernan, 2005).**

Limitations and recommendations of the study

Several shortcomings of the present study are worth mentioning. The current study included children with age ranging from 8 to 15 years that some may argue that this is a wide range of age. However, future studies are recommended on different age groups. A second limitation is that the participants were included if diagnosed with CKD regardless the cause and duration of the disease. Further studies are needed to analyze the duration effect and underlying cause of the disease on balance. Although the results showed significant impairments in balance in children receiving hemodialysis, the duration and number of dialysis treatments weren't reported in the current study. The authors highly recommend for further studies to analyze the effect of hemodialysis on balance. Finally, the authors highly recommend longitudinal studies among that population to identify future health related challenges.

CONCLUSION

Children with CKD have balance impairments regardless the cause and duration of the disease. Children receiving hemodialysis have significant impairments when compared with non-dialysis CKD.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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ضعف التوازن لدى الأطفال المصابين بأمراض الكلى المزمنة

(دراسه مقطعية)

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الخلفية: يرتبط مرض الكلى المزمن بإعتلالات مصاحبة التى تؤدى إلى اختلال التوازن. **الغرض من البحث**: دراسة ضعف التوازن لدى الأطفال المصابين بمرض الكلى المزمن مقارنة بالاطفال الطبيعيين من نفس الفئة العمرية. العينة أساليب البحث: من إجمالى 75 طفل ، تتراوح أعمارهم بين 8 و 15 تمثل ثلاث مجموعات بأعداد متساوية ؛ المجموعة الضابطة (الاطفال الطبيعيين) ، لا يتلقون الغسيل الكلوى (المرحلة 2 إلى 4) ومجموعة تتلقى الغسيل الكلوى. تم تقييم التوازن بواسطة نظام ميزان حاسوب التقييم البشرى (HUMAC). **النتائج**: بالمقارنة مع الأطفال الطبيعيين ، أظهر الأطفال الذين يعانون من CKD إنخفاض فى الاتزان ذا دلالة إحصائية (P <0.05). أظهر هؤلاء الذين يتلقون الغسيل الكلوى إنخفاضاً ملحوظًا مقارنةً بالمجموعة الذين لا يتلقون الغسيل الكلوى. **الخلاصة**: يعانى الأطفال المصابون بمرض الكلى المزمن من خلل فى التوازن بغض النظر عن سبب ومدة المرض.

الكلمات الدالة: التوازن ، أمراض الكلى المزمنة ،HUMAC

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