A Community-Linked Model for the Management of Children's Mental and Physical Health

Peilin NIU[1]*

Abstract

With the rise of exercise psychology, the society is attaching greater importance to the physical and mental health of children and youngsters. If sports intervention is implemented persistently, children and youngsters will have a tougher mind, a higher confidence, and a stronger resistance to setbacks. However, the relevant literature lacks quantitative analysis, and fails to study the mediating effect of sports perseverance mechanism. Thus, this paper explores the cultivation and regression analysis of children's mental toughness under the intervention of sports perseverance mechanism. Firstly, a model was established to analyze the sports perseverance intervention facing children's mental toughness. Next, a multi-factor cointegration test was performed on the time series of the quantified values of children's mental toughness under the intervention of sports perseverance. In addition, the error correction model and breakpoint regression model were constructed to determine the moments that the time series deviate from the equilibrium state and return to the normal state. The test results of the proposed models were obtained through experiments, which verify the effectiveness of these models.

Keywords: sports perseverance mechanism; children's mental toughness; regression analysis

1. Introduction

We live in the age of technology. Technology is the backbone of our world and is used in nearly every profession imaginable. Every day, people are spending more and more time on their mobile devices or computers with attention split between real-life interactions and electronics consumption (Xu, Wu, & Zhu, 2021). We have seen how these devices can be beneficial to learning, creativity, and productivity; but we are also seeing the negative effects they can have on our physical health - so what about mental health?

Mental illnesses are just as real as physical ones. But for some reason, we put a stigma on them that seems less tangible than something you can physically see like an injury or skin rash. Mental illnesses (e.g. anxiety, depression) are a large part of the reason why we are seeing such high suicide rates among teens and young people. In fact, in 2015, suicide was the 2nd highest cause of death for ages 10-24 years old in the United States (Gabrielli et al., 2018; Hankala et al., 2017).

Over time, we have been able to understand that mental health is just as important as physical health; however, it can be difficult to find professionals who specialize in working with young people (most psychologists are older and may not be familiar with current technology trends). Further - some research has shown that many young people don't like going to the doctor because of stigma associated with psychological issues (Fergeus et al., 2017).

To try and bridge this gap, I have developed Bridging the Gap (BTG) to provide a community-organized service to help prevent suicide among youth. BTG is a mobile app created for people who are age 12-24 and between the ages of 12-25. The app seeks to understand what is being done in your home or school to prevent suicide, and then offers a host of services that can be accessed by parents, teachers/school administrators, or other people in our community to help with suicidality. For example, BTG has an Appointment Scheduler that allows users to make appointments with professionals (e.g. therapist, dancer) by providing a secure and private platform that allows users to choose a time (e.g. after school or during lunch) that fits their schedule (Liu, 2021; Turner et al., 2021; Wang et al., 2018).

BTG also hosts a Peer Support/Triage service. This service is designed for mental health professionals and other community members to send messages to youth who may be experiencing high levels of distress so that we can try and assess the situation right then and there in order to provide more immediate/concentrated support (vs. waiting days or weeks).

The problem is, if you don't take care of your mental health, your physical health will also suffer. Think about it - If you are depressed or anxious and you can't get out of bed - then how can you care for yourself properly? how can you make healthy choices in what you eat and whether or not you

[1] School of Education science,Yulin Normal College ,Yulin Guangxi,537000, China

*Corresponding Author E-mail: 18269216799niu@sina.com

exercise? without having a healthy mental health foundation, then your physical health can be negatively affected as well.

One of our goals at Bridging the Gap is to help people who are struggling with mental health issues get back on their feet, and to provide an infrastructure that allows users to communicate with each other in a secure, private space. We are working towards making it easier for people to access services that they need, and get better (Yue & Fangli, 2018; Zhang, 2020).

We have found that we have a great opportunity to provide an effective community-based solution for the prevention of suicide among our young people. We hope that this study will help us to move towards our goals and create a better future for the world's youth.

So who is BTG?

BTG is a mobile app created for youth (ages 12-24) who are between the ages of 12-25. It was designed recently and is in its infancy, with plans to grow into a larger system. The app is currently available in both Apple and Android stores. Users can access the app through iOS or Android devices. The BTG team is made up of two people: myself, who developed the app and created most of the initial functionality - and a friend of mine who helps us with coding for Android (as well as other tasks). We are also working on a website, but need to finish that before we submit it to Apple & Google for approval (Palit & Chatterjee, 2006; Shojaei-Miandoragh, Bijani, & Abbasi, 2020).

What is Bridging the Gap?

Bridging the Gap was created as a community-based service platform to help reduce suicidality among youth aged 12-24 in order to help prevent suicide. We are currently developing a mobile Android and iOS app to help bridge the gap between mental health professionals and the young people in our lives (Ab-Rahim et al., 2021). Our services are designed to be accessible by anyone in the community - whether it be a parent, teacher, or other person who is able to provide support. Currently, we have four core services that we offer on BTG: 1) Appointment Scheduler: This allows users to make appointments with professionals (e.g. therapist, dancer) by providing a secure and private platform that allows users to choose a time (e.g. after school or during lunch) that fits their schedule.

The goal of this project is to help young people address their mental health issues. We want to use the latest technology trends (e.g. social media), design thinking processes, and community outreach to make young people realize they are not alone when it comes to their experiences with poor mental health (Gao, Qiao, & Mei, 2019; Wang, 2017).

2. Modeling of the Intervention of Sports Perseverance Mechanism

Long-term regular physical exercise has a prominent promoting effect on physiology and mental health. It helps to reduce negative responses (e.g., anxiety and depression), and enhance positive responses (e.g., self-efficacy, health, and energy). The children insisting on participating in physical exercise have a relatively good mental health and a relatively high mental toughness, both of which are directly dependent on the exercise intensity. As a way to enhance mental toughness, physical exercise can be used to guide and cultivate children, and enable them to avoid mental problems (e.g., anxiety and depression) under a large learning pressure. The key of physical exercise lies in the experience of participation and perseverance. Through physical exercise, children's thinking and spirit will be refreshed, kicking off a virtuous cycle of mental balance, mental activation, cognitive adjustment, and behavioral change (Li & Liu, 2012; Zhang et al., 2021).

This section mainly analyzes the action mechanism of sports perseverance intervention on children's mental toughness, and builds up the following analysis model for sports perseverance intervention facing children's mental toughness. Let C_τ be the variation of the mean function; M_τ be the autoregressive integrated moving average (ARIMA) model; $\{M_\tau\}$ be the original time series of the quantified values of children's mental toughness without sports perseverance intervention. Then, the general intervention model $\{B_\tau\}$ can be expressed as:

$$B_\tau = C_\tau + M_\tau \quad (1)$$

Suppose the time series is affected by sports perseverance intervention at moment Φ. Then, the time series $\{B_\tau, \tau<\Phi\}$ can be defined as the preintervention data of sports perseverance, and used to recognize the model for the basic series $\{M_\tau\}$ without any intervention.

The step function and pulse function can characterize the influence of sports perseverance intervention over the mean function of the quantified values of children's mental toughness. If sports perseverance intervention causes a permanent deviation of that function, then sports perseverance intervention must have a long-lasting impact on children's mental toughness. The variable of sports perseverance intervention can be described by the following step dummy variable:

$$E_\tau^{(\Phi)} = \begin{cases} 1, \tau \geq \Phi \\ 0, Otherwise \end{cases} \quad (2)$$

If sports perseverance intervention only takes place at moment Φ, vanishes after one or several cycles, and exerts a short-term effect on the mean function, that is, the effect of sports perseverance intervention lasts shortly in one or

several cycles, then the variable of sports perseverance intervention can be described by the following pulse dummy variable:

$$Q_\tau^{(\Phi)} = \begin{cases} 1, \tau \geq \Phi \\ 0, Otherwise \end{cases} \quad (3)$$

According to the number of influencing cycles of sports perseverance intervention, and its influence on the mean function of the quantified values of children's mental toughness, sports perseverance intervention can be divided into four types:

(A) If there are many influencing cycles, the influence of sports perseverance intervention over the mean function can be regarded as permanent. Let φ be the permanent change to the mean of the quantified values of children's mental toughness induced by sports perseverance intervention. Then, this type of sports perseverance intervention can be modeled as:

$$C_\tau = \phi E_\tau^{(\Phi)} \quad (4)$$

Since φ is unknown, the change intensity of the mean of the time series is not known. If the influence of sports perseverance intervention is delayed by r cycles, then this type of sports perseverance intervention can be modeled as:

$$C_\tau = \phi E_{\tau-r'}^{(\Phi)} \quad (5)$$

(B) In real life, sports perseverance intervention does not necessarily take effect immediately. In most cases, sports perseverance intervention has a gradual and lasting impact on children's mental toughness. Then, this type of sports perseverance intervention can be modeled as:

$$C_\tau = \frac{\phi W}{1-\beta W} E_\tau^{(\Phi)}, 0 < \beta < 1 \quad (6)$$

(3) Sports perseverance intervention occurs suddenly, and vanishes after one or several cycles. In this case, it only affects the mean function in a short time. Then, this type of sports perseverance intervention can be modeled as:

$$C_\tau = \phi Q_\tau^{(\Phi)} \quad (7)$$

(4) Sports perseverance intervention occurs suddenly, gradually weakens, and vanishes after one or several cycles. In this case, it only has a short-term impact on the mean function. Then, this type of sports perseverance intervention can be modeled as:

$$C_\tau = \frac{\phi W}{1-\beta W} Q_\tau^{(\Phi)}, 0 < \beta < 1 \quad (8)$$

The above types of sports perseverance intervention can be combined into a complex model for the influence of sports perseverance intervention over children's mental toughness:

$$C_\tau = \frac{\phi_1 W}{1-\beta W} Q_\tau^{(\Phi)} + \frac{\phi_2 W}{1-W} Q_\tau^{(\Phi)} \quad (9)$$

Or:

$$C_\tau = \phi_0 Q_\tau^{(\Phi)} + \frac{\phi_1 W}{1-\beta W} Q_\tau^{(\Phi)} + \frac{\phi_2 W}{1-W} Q_\tau^{(\Phi)} \quad (10)$$

Before applying the model of sports perseverance intervention, the attributes of sports perseverance intervention must be analyzed in the light of the actual situation. The model parameters can be determined through maximum likelihood estimation.

3. Cointegration Test and Regression Analysis

3.1 Cointegration test

The cointegration relationship between multiple factors of the time series of the quantified values of children's mental toughness under sports perseverance intervention can be verified through the Johansen tests for cointegration. The multiple factors include the number of cycles for sports perseverance intervention, the type of physical exercise, the presence/absence of teacher accompaniment, etc. This paper develops the mathematical models for error correction and breakpoint regression, aiming to determine the moments that the time series of the quantified values of children's mental toughness under sports perseverance intervention deviate from the equilibrium state and return to the normal state (Cai & Jin, 2021; Kushwaha & Hajare, 2021).

If there is a cointegration relationship within the time series of u quantified values of children's mental toughness, then the long-term relationship between the time series variables capable of characterizing the influence degree of sports perseverance intervention can be expressed as:

$$\delta_1 a_{1s} + \delta_2 a_{2s} + \ldots + \delta_u a_{us} = 0 \quad (11)$$

Formula (11) can be converted into a matrix:

$$A_s' \delta = 0 \quad (12)$$

where, A_s and δ can be calculated by:

$$A_s = \begin{bmatrix} a_{1s} \\ a_{2s} \\ \cdots \\ a_{us} \end{bmatrix}, \delta = \begin{bmatrix} \delta_1 \\ \delta_2 \\ \cdots \\ \delta_u \end{bmatrix} \quad (13)$$

Through the cointegration regression, it is possible to obtain the time series of the residual for the quantified values of children's mental toughness under sports perseverance intervention. Then, the residual series were subjected to the Johansen tests for cointegration in two steps: trace test and maximum characteristic root test.

The trace test verifies all characteristic roots. The assumed condition for the cointegration relationship can be described by:

$$\begin{cases} G': There\ are\ at\ most\ q\ cointegration\ relationships; \\ G'': There\ are\ n\ cointegration\ relationships. \end{cases} \quad (14)$$

Suppose there are SA observed samples of children's mental toughness. Ranking all characteristic roots in descending order, the i-th characteristic root is denoted as μ_i. Then, the statistic can be expressed as:

$$TJ_{trace}(q|n) = -SA\sum_{i=q+1}^{n} log(1-\mu_i) \quad (15)$$

In the maximum characteristic root test, the assumed condition for adjusting the cointegration relationship can be described by:

$$\begin{cases} G_q^{'}: There\ are\ at\ q\ cointegration\ relationships; \\ G_q^{''}: There\ are\ at\ least\ q+1\ cointegration\ relationships. \end{cases} \quad (16)$$

The statistic expression can be updated by:

$$TJ_{max}(q|q+1) = -SA\ log(1-\mu_{q+1}) = TJ_{trace}(q|n) - TJ(q+1|n) \quad (17)$$

where, q=0, 1, ..., n-1. The test starts from G'_0. If the null hypothesis is not rejected, then there is no cointegration relationship within in the time series. If the null hypothesis is rejected, the test will be implemented on G'_1. If the null hypothesis is not rejected, then there is no cointegration relationship within in the time series. If the null hypothesis is rejected, the test will be implemented on G'_2. The cointegration test on G'_3,...,G'_q is performed by analogy, until the null hypothesis is not rejected.

On the time series of the quantified values of children's mental toughness under sports perseverance intervention, the Johansen tests for cointegration could bring five different results.

Let $CO_{\tau-1}$ be the cointegration vector. If variable B_τ contains no deterministic trend term and vector $CO_{\tau-1}$ contains no intercept term or trend term, then:

$$\begin{cases} \Psi^*(K)\Delta B_\tau = FP'CO_{\tau-1} + V_\tau = F \cdot CO_{\tau-1} + V_\tau \\ CO_{\tau-1} = P'B_{\tau-1} \end{cases} \quad (18)$$

The above situation is rarely the case in reality. If variable B_τ contains no deterministic trend term and vector $CO_{\tau-1}$ contains only the intercept term, then:

$$\begin{cases} \Psi^*(K)\Delta B_\tau = F \cdot CO_{\tau-1} + V_\tau \\ CO_{\tau-1} = P'B_{\tau-1} + d_0 \end{cases} \quad (19)$$

Any time series depicted by the above formula contains no trend term. If variable B_τ contains a linear trend term and vector $CO_{\tau-1}$ contains only the intercept term, then:

$$\begin{cases} \Psi^*(K)\Delta B_\tau = N_\tau + F \cdot CO_{\tau-1} + V_\tau \\ CO_{\tau-1} = P'B_{\tau-1} + d_0 \end{cases} \quad (20)$$

Any time series depicted by the above formula contains a stochastic trend term. If variable B_τ contains a linear trend term and vector $CO_{\tau-1}$ contains both the intercept term and the trend term, then:

$$\begin{cases} \Psi^*(K)\Delta B_\tau = N_\tau + F \cdot CO_{\tau-1} + V_\tau \\ CO_{\tau-1} = P'B_{\tau-1} + d_0 + d_1\tau \end{cases} \quad (21)$$

Any time series depicted by the above formula has a stable trend, i.e., contains both stochastic trend series and deterministic trend series. If variable B_τ contains a quadratic trend term and vector $CO_{\tau-1}$ contains both the intercept term and the trend term, then:

$$\begin{cases} \Psi^*(K)\Delta B_\tau = N_\tau[1,\tau]' + F \cdot CO_{\tau-1} + V_\tau \\ CO_{\tau-1} = P'B_{\tau-1} + d_0 + d_1\tau \end{cases} \quad (22)$$

The above situation is rarely the case in reality.

3.2 Regression analysis

Under real sports perseverance intervention, the variation of children's mental toughness is not always stable or balanced. In the short term, the cointegration relationship of the time series will deviate from the normal value, when it is disturbed by school work or family issues. This paper sets up an error correction model to analyze the deviation from the cointegration relationship (Puswiartika & Gatot, 2020; Yablonsky, 2021).

Let b be the explained variable; a be the explanatory variable. Suppose the error correction model based on the residual series obtained in the preceding subsection contains only one b_τ and one a_τ. Let $E_{\tau-1}$ be the error correction term in the model. Then, the error correction model can be expressed as:

$$\Delta b_\tau = \gamma_0 + \gamma_1\Delta a_\tau + \mu E_{\tau-1} + \eta_\tau \quad (23)$$

The derivation process can be explained as:

$$b_\tau = \xi_0 + \xi_1 a_\tau + \xi_2 b_{\tau-1} + \xi_3 a_{\tau-1} + \eta_\tau \quad (24)$$

Subtracting $b_{\tau-1}$ from both sides of the above equation,

$$b_\tau - b_{\tau-1} = \xi_0 + \xi_1 a_\tau + (\xi_2 - 1)b_{\tau-1} + \xi_3 a_{\tau-1} + \eta_\tau \quad (25)$$

Subtracting $\xi_1 a_{\tau-1}$ from and adding $\xi_1 a_{\tau-1}$ to the right side of the above equation,

$$\begin{aligned} &\Delta b_\tau = \xi_0 + \xi_1(a_1 - a_{\tau-1}) + (\xi_2 - 1)b_{\tau-1} + (\xi_1 + \xi_3)a_{\tau-1} + \eta_\tau \\ &\xi_0 + \xi_1\Delta a_\tau + (1-\xi_2)b_{\tau-1} + (\xi_1 + \xi_3)a_{\tau-1} + \eta_\tau \\ &\xi_0 + \xi_1\Delta a_\tau + (1-\xi_2)\left(b_{\tau-1} - \frac{\xi_1+\xi_3}{1-\xi_2}a_{\tau-1}\right) + \eta_\tau \end{aligned} \quad (26)$$

where, $E_{\tau-1}$ falls in [-1, 1]. The greater the absolute value of $E_{\tau-1}$, the faster the quantified values of children's mental toughness returns to the normal state with the elapse of time. The proposed error correction model involves three terms: the fluctuation Δb_τ of b_τ, the fluctuation Δa_τ of a_τ, and the equilibrium error $E_{\tau-1}$. The above formulas indicate that Δb_τ is jointly determined by Δa_τ and $E_{\tau-1}$. The meaning of Δa_τ should be defined according to the actual changes of such factors as the number of cycles for sports perseverance intervention, the type of physical exercise, the presence/absence of teacher accompaniment, etc. $E_{\tau-1}$ depicts how much the quantified values of children's mental toughness under sports perseverance intervention deviate from the equilibrium state in the short term.

Finally, this paper establishes a breakpoint regression model for the variation in children's mental toughness under sports perseverance intervention. The grouping variable can be expressed as the following indicative function U_i:

$$U_i = \begin{cases} 1, a_i \geq w \\ 0, a_i < w \end{cases} \quad (27)$$

If an explanatory variable a_i is greater than threshold w, U_i=0; if a_i is smaller than w, U_i=1. In the latter case, U_i goes through discontinuous changes. If the discontinuous changes only occur to a_i and b near the breakpoint, then the variation of b must be driven primarily by a_i. The breakpoint is located at threshold w. Let A-w be the

movement of the explanatory variable A of the explained variable B to the zero point; λ be the coefficient of the grouping variable U. Then, the regression function of the breakpoint regression model can be expressed as:

$$B = \gamma_s + \lambda U + \theta_k(A - w) + (\theta_q - \theta_k)U(A - w) + \eta$$
$$w - g \le A \le w + g \qquad (28)$$

Model (28) is restricted within a distance of g from either side of w. If g is small, the fitted curve can be approximately regraded as linear, and the linear fitting approach can be adopted. If the regression equation is not symmetric about the breakpoint, then the two equations must differ in slope. This difference needs to be tolerated for the interactive term. Let θ_k and θ_q be the slope of the regression equation on the left and right of point w, respectively. Then, this paper builds $(\theta_q\text{-}\theta_\tau)U(A\text{-}w)$ based on linear function and binary variable U, and treats it as the interactive term that ensures the slope difference of linear function across point w, making the linear function smoother.

4. Experiments and Results Analysis

Based on the previous analysis, this paper fits three ARIMA models, namely, ARIMA (1,1), ARIMA (1,0), and ARIMA (0,1), and carries out intervention model fitting and residual series white noise tests on the time series of the quantified values of children's mental toughness under sports perseverance intervention. Table 1 lists the white noise test results on the residual series. Whether the lag is five or ten, the p-value of all three models was far greater than the critical value, indicating that the three ARIMA models all pass the white noise tests. In other words, the three models have a significant effectiveness for fitting the time series of the quantified values of children's mental toughness under sports perseverance intervention. The minimum information criteria of different models were similar (AIC and BIC). However, ARIMA (1,0) had smaller AIC and BIC than the other two models. As a result, this model was selected for fitting.

Table 1

White noise test results on the residual series

Models		ARIMA (1,1)	ARIMA (1,0)	ARIMA (0,1)
P-value	5 lags	0.9685	0.8596	0.9528
	10 lags	0.7258	0.758	0.8216
Minimum information criterion AIC value		1472.62	1485.26	1452.12
Minimum information criterion BIC value		1485.225	1495.214	1485.254

Note: AIC and BIC are short for Akaike Information Criterion and Bayesian Information Criterion, respectively.

The original data were obtained through mental toughness tests on the students of a primary school in Suzhou, southeastern China's Jiangsu Province from February to July, 2018. Our sports perseverance intervention model was established on these data, and used to predict the data from February to July, 2019. The relative error between the predicted values and the actual values in the prediction period was computed (Table 2).

Table 2

Prediction results of the intervention model

Time	February 2019	March 2019	April 2019
Actual value	6.8594	7.2815	8.5721
Predicted value	6.4827	6.9843	9.0234
Relative error	0.3767	0.2972	-0.4513
Time	**May 2019**	**June 2019**	**July 2019**
Actual value	6.9823	5.8263	5.6847
Predicted value	7.3426	6.5129	5.5174
Relative error	-0.3603	-0.6866	0.1673

As shown in Table 2, the relative error between actual values and predicted values was rather small, suggesting that our sports perseverance intervention model can accurately describe the time variable of the quantified values of children's mental toughness. Under the influence of sports perseverance intervention, the model for the time series of the quantified values of children's mental toughness cannot effectively analyze the intervention of multiple factors in the development of children's mental toughness. Fortunately, the proposed intervention model can clarify the intervention effect and intervention mechanism, and precisely predict the trend of children's mental toughness under sports perseverance intervention.

Tables 3 and 4 present the trace test results and maximum characteristic root test results of the residual time series for the quantified values of children's mental toughness under sports perseverance intervention.

Table 3

Trace test results on the residual time series

Number of cointegration relationships	0	1	2	3	4	5
Characteristic root	0.742851	0.682135	0.274851	0.182437	0.143295	0.051273
Trace statistic	186.2842	108.2914	45.28175	26.47231	13.92468	4.28617
P-value	0.0001	0.0263	0.0495	0.0429	0.0916	0.0826

Table 4

Maximum characteristic root test results on the residual time series

Number of cointegration relationships	0	1	2	3	4	5
Characteristic root	0.782465	0.618248	0.274129	0.183492	0.162873	0.058216
Trace statistic	82.18245	58.36274	26.48237	18.72648	14.29187	3.18246
P-value	0.0002	0.0006	0.4285	0.2761	0.1628	0.0829

The row of the number of cointegration relationships records the maximum number of multi-factor cointegration relationships in the time series of the quantified values of children's mental toughness under sports perseverance intervention. It can be seen that, on the significance level of 5%, there were at most three cointegration relationship, provided that the null hypothesis was not rejected. Therefore, there exist three cointegration relationships between the five influencing factors, namely, the number of cycles for sports perseverance intervention, the type of physical exercise, the organizational form of physical exercise, the duration of each physical exercise, and the presence/absence of teacher accompaniment. Table 5 shows the statistics on the regression coefficient of each factor.

Table 5

Statistics on regression coefficients after normalizing the cointegration equation

	Normalization coefficient	Standard deviation	t-statistic
B_{i-1}	1.0002	1.0013	None
$Ln(A2_{i-1})$	-4.251746	3.256412	-1.45281
$Ln(A3_{i-1})$	16.50263	5.24712	2.85471
$A4_{i-1}$	-19.25481	2.21635	4.26581
$A5_{i-1}$	-13.25462	*None*	-3.26548

The Johansen tests for cointegration confirm the quantified values of children's mental toughness has a long-term equilibrium relationship with the five influencing factors. If the relationship has short-term deviation, the deviation should be corrected by the proposed error correction model, such that the relationship returns to the original state.

Our error correction model is grounded on the Johansen tests for cointegration. Thus, the order of delay is the post-difference order, i.e., the lag equals five. Table 6 presents the coefficients of the model containing three cointegration relationships.

Table 6

Statistics on the coefficients of error correction model

	Correction coefficient	Standard deviation	t-statistic		Correction coefficient	Standard deviation	t-statistic
$E_{1,\tau=1}$	-0.075214	0.21546	-0.52863	$U(A1(-1))$	-0.182738	0.15385	-0.62284
$E_{2,\tau=2}$	0.042746	0.05758	0.52816	$U(A1(-2))$	0.031572	0.14228	0.27237
$U(B(-1))$	0.831526	0.18246	4.57298	$U(A1(-3))$	0.258273	0.12594	2.18138
$U(B(-2))$	-0.648294	0.37296	-2.68195	$U(A1(-4))$	-0.047374	0.11012	-0.38274
$U(B(-3))$	0.475295	0.17293	2.38589	$U(A2(-1))$	-8.362643	13.24847	-0.66275
$U(B(-4))$	-0.162863	0.24825	-0.86175	$U(A2(-2))$	-25.184829	11.13863	-1.64834

	Correction coefficient	Standard deviation	t-statistic		Correction coefficient	Standard deviation	t-statistic
$U(A2(-3))$	2.628574	16.12835	0.25937	$U(A4(-1))$	3.572859	2.528647	1.63728
$U(A2(-4))$	14.23859	17.19447	0.92758	$U(A4(-2))$	0.638728	2.371864	0.35327
$U(A3(-1))$	-0.06728	4.51618	-1.78386	$U(A4(-3))$	2.362586	2.37596	1.43365
$U(A3(-2))$	-1.362748	4.237594	-0.436752	$U(A4(-4))$	-0.682736	2.65737	-0.36157
$U(A3(-3))$	-5.182758	4.627854	-1.37472	$U(A5(-1))$	-2.473759	4.62795	-0.63534
$U(A3(-4))$	6.479264	4.483875	1.27538	$U(A5(-2))$	-1.682539	5.82647	-0.43278
	Correction coefficient	Standard deviation	t-statistic		Correction coefficient	Standard deviation	t-statistic
$U(A5(-3))$	-12.378847	4.71826	-2.48275	$U(A5(-4))$	2.546811	4.75213	0.59683

After logarithmic and differential treatment, the goodness-of-fit of the proposed error correction model could reach 0.845571. This means our model can fit the quantified values of children's mental toughness excellently. In addition, both AIC and BIC were small, respectively 3.24515 and 4.21883. Thus, the model can accurately reflect the error correction situation.

Figure 1 provides the breakpoint map of the quantified values of children's mental toughness. It can be observed that the quantified values jumped, evidence to the breakpoint effect of different sports perseverance stages on children's mental toughness.

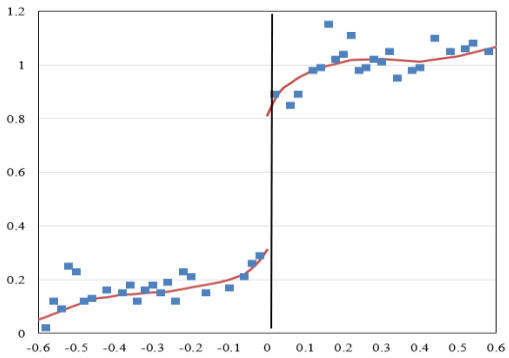

Figure 1. Third-order function fitting results of the breakpoint regression model

Table 7

Correlations between the stages of sports perseverance intervention and the cultivation of children's mental toughness

	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}
x_1	1	-0.258	-0.163	-0.153	-0.284	-0.226	-0.258	-0.425	-0.163	-0.258	-0.135
x_2		1	0.162	0.164	0.147	0.251	0.235	0.183	0.164	0.152	0.327
x_3			1	0.114	0.251	0.342	0.162	0.284	0.316	0.249	0.163
x_4				1	0.262	0.286	0.015	0.146	0.258	0.158	0.147
x_5					1	0.2548	0.327	0.185	0.2538	0.158	0.249
x_6						1	0.315	0.132	0.157	0.225	0.315
x_7							1	0.241	0.295	0.214	0.154
x_8								1	0.254	0.213	0.324
x_9									1	0.362	0.254
x_{10}										1	0.258
x_{11}											1

Table 7 provides the correlation analysis results between the stages of sports perseverance intervention and the cultivation of children's mental toughness. The specific stages include the unintentional stage of physical exercise behavior, the intentional stage of physical exercise behavior, the family support stage, the imitation stage of physical exercise behavior, the preparation stage of physical exercise behavior, the teacher assistance stage, the active participation stage of physical exercise, and the maintenance stage of physical exercise. For clarity, these eight stages are denoted by x_1, x_2, x_3, x_4, x_5, x_6, x_7 and x_8, in turn. In addition, the confidence formation, concentration formation, and mental toughness formation during the cultivation of children's mental toughness are denoted by x_9, x_{10}, and x_{11}, respectively.

According to the results of the correlation analysis (Table 6), the unintentional stage of physical exercise behavior has a negative correlation with the confidence formation, concentration formation, and mental toughness formation. Meanwhile, the other seven stages have a positive correlation with the confidence formation, concentration formation, and mental toughness formation.

The above analysis shows that, it is easier for the children in the intentional stage of physical exercise behavior, the active participation stage of physical exercise, or the maintenance stage of physical exercise, to improve their confidence, concentration, and mental toughness than those in the unintentional stage of physical exercise behavior, because the former group has started doing physical exercise, and won the support from teachers and families. That is, the sports perseverance mechanism has a positive correlation with the cultivation of children's mental toughness. A possible reason is that the children, who have started doing physical exercise and even gotten used to physical exercise, tend to be energetic, lead a colorful life, possess a positive attitude towards learning and life, and do well in coping with pressure.

5. Conclusions

This paper mainly examines the cultivation of children's mental toughness under the intervention of sports perseverance mechanism. The first step is to build an analysis model for sports perseverance intervention in the context of children's mental toughness, and perform a multi-factor cointegration test on the time series of the quantified values of children's mental toughness under sports perseverance intervention. Next, an error correction model and a breakpoint regression model were constructed to determine when the time series deviate from the equilibrium state, and return to the normal state. After that, three ARIMA models, namely, ARIMA (1,1), ARIMA (1,0), and ARIMA (0,1), were adopted for model fitting test and residual series white noise test, concerning the time series of the quantified values of children's mental toughness under sports perseverance intervention (Zahran et al., 2011).

During the experiments, the actual values of February to July, 2019 were compared with the predicted values of the sports perseverance intervention model. The relative errors between the two sets of values demonstrate the effectiveness of the model. In addition, the residual time series for the quantified values of children's mental toughness under sports perseverance intervention were subjected to trace test and maximum characteristic root test. The test results indicate that, there were at most three cointegration relationship, provided that the null hypothesis was not rejected. After the cointegration equation was normalized, the regression coefficients and the coefficients of the error correction model were summarized, and the correlations between the stages of sports perseverance intervention and the cultivation of children's mental toughness were analyzed. The relevant results reveal the good fitting effect of our model on the quantified values of children's mental toughness.

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