Int. J. Sport Psychol., 2024; 55: 280-296
doi: 10.7352/IJSP.2024.55.280

Using physical literacy to predict physical activity among university students: a machine learning logistic regression model

Xiaoxi Dong*, Zengying Yan**, Jiangzhou Deng, Heather Johanson Desiral****, Menglin Xu*****, Fan Huang********

(*) *Department of Sports Teaching and Research, Lanzhou University, Lanzhou, Gansu, 730000, P. R. China*
(**) *School of Physical Education, Chongqing University of Posts and Telecommunications, Nan'an District, Chongqing, 400065, P.R. China*
(***) *School of Economics and Management, Chongqing University of Posts and Telecommunications, Nan'an District, Chongqing, 400065, P.R. China*
(****) *Adrian Dominican School of Education, Barry University, 11300 NE 2nd Ave Miami, FL 33161, United States*
(*****) *Department of Internal Medicine, Ohio State University, 281 W Lane Ave, Columbus, OH 43120, United States*
(******) *Faculty of Education, University of Macau, Taipa, Macau, P.R. China*

Physical inactivity has become an increasingly challenging concern for health systems and policymakers globally. The purpose of this study was to examine whether physical literacy could be used to predict the physical activity behaviors of Chinese university students in order to provide an efficient tool for encouraging public health. 1,591 Chinese university students (females = 813, males = 778) with a mean age of 19.63 years (SD = 1.36) participated in this study. Findings indicated a practical machine learning logistic regression model (LRM) for predicting PA behaviors among university students. The accuracy on the confusion matrix was .715, and the Receiver operating characteristic curve and Concordance test indicated that the LRM is a good model. The researchers conclude that the present LRM can be a useful tool for higher education institutions to monitor and foster students' PA behaviors to promote a healthy lifestyle and life-long participation in physical activities.

KEY WORDS: Physical literacy, Physical activity, Logistic regression, Machine learning.

Introduction

Physical activity (PA) is a significant contributory factor in fostering healthy living. According to Warburton et al. (2006), an increase in PA is as-

Correspondence to: Fan Huang. E33 Av. da Universidade, Taipa, Macau, China. (E-mail: hefu411@126.com)

sociated with a reduction in risky diseases, including cardiovascular disease, diabetes mellitus and cancers. Conversely, physical inactivity (PI) is a substantial risk factor contributing to noncommunicable diseases and leading to global mortality (WHO, 2010). PI has become a serious challenge, impacting the quality of life for humans, as the prevalence of PI has been increasing among various populations across the world (Dumith et al., 2011; Guthold et al., 2020; Guthold et al., 2008). WHO (2018) indicated that around 23% of the adult population and 81% of the adolescent population aged from 11 to 17 years old do not reach the level of PA for benefiting healthy development worldwide, recommended by WHO (2010). The prevalence rate for PI was consistent with the study conducted by Guthold et al. (2020), who found that around eight out of ten adolescents have insufficiently participated in PA for advancing healthy living across 146 countries. Meanwhile, Pengpid et al. (2015) reported that in 23 countries studied, around four out of ten college students have had inadequate levels of participation in PA for promoting individuals' health. In responding to the challenge of the global prevalence of PI, WHO (2018) proposed a global PA action plan, which aims to decrease the prevalence rate of PI for the adult and adolescent population worldwide by 2030.

Currently, the concept of physical literacy (PL) has been embraced as an educational goal for diminishing the harmful impacts of PI worldwide (Castelli et al., 2015; Sum & Whitehead, 2021). According to Whitehead (2001), the conceptualization of PL was rooted in the philosophies of existential and phenomenological perspectives to fulfill individuals' potential. Human existence is the main standpoint of PL, which offers opportunities for individuals to promote a healthy quality of life by experiencing an enriching environment (Giblin et al., 2014). Moreover, the theory of PL emphasizes a holistic concept that consists of multidimensional domains: physical, cognitive, affective and behavioral (Cairney et al., 2019; Whitehead, 2010). In addition, Whitehead (2010) highlighted that the PL domains have a reciprocal relationship to complement one another to promote holistic development, which ultimately increases a healthy quality of life. The holistic nature of PL encompasses a core component of a learning experience that interacts with the physical world (Edwards et al., 2017). Dudley (2015) pointed out that the nature of PL empowers potential learning via movement. Besides, the holistic concept of PL may encourage individuals to gain knowledge of PA and physical skills through the process of integration between mind and body (Chen, 2015). Studies have revealed a positive association between PL and PA among different populations in the world (Caldwell et al., 2020; Choi et al., 2018). For instance, Caldwell et al. (2020) found a significant positive

association between PL and moderate and vigorous-intensity PA with a sampled population of children in Canada. The findings of Caldwell et al. (2020) indicated that the children who experienced a higher degree of PL engaged in more moderate and vigorous-intensity PA. Likewise, Choi et al. (2018) found a similar result, in that there was a significant positive association between perceived PL and PA among adolescents in Hong Kong.

PL has been adopted by numerous countries as the desired goal of quality physical education for encouraging individuals to cultivate a lifelong physically active lifestyle (Castelli et al., 2015; Shearer et al., 2021). For instance, the Society of Health and Physical Educators (SHAPE) America (2014) adopted PL as the desired goal to develop *National Standards and Grade-Level Outcomes for K-12 Physical Education* in the United States of America. In addition, the national standards would deliberately highlight holistic development in promoting a habit of participation in physical activity, while building up physically active lifestyles (SHAPE America, 2014). Likewise, Keegan et al. (2013) illustrated that the concept of PL was adopted by Australia with the program of *Getting Australia Moving: Establishing a Physically Literate Active Nation (Game Plan)* for cultivating life-long skillful participation in PA with positive affective attitudes and health-related knowledge of PA.

The attractive feature of PL is not only to promote participation in PA, but it also benefits individuals' health. However, the concept of PL is relatively new, and more studies are needed to investigate its potential, especially in Eastern countries (Sum & Whitehead, 2021). Meanwhile, Haase et al. (2004) and Pengpid et al. (2015) pointed out that the worldwide prevalence of PI is a serious challenge because of the impact it has on decreasing university students' healthy living around the world. Moreover, the levels of Chinese college students' physical fitness have displayed a declining trend between 2014 and 2016 (Chen et al., 2020). Ma et al. (2020) conducted a study to examine the relationship between PL and the level of PA among Chinese university students and reported a significant positive relationship between PL and the levels of PA among Chinese university students. Therefore, there is a reasonable assumption that physical literacy would be used to predict physical activity among Chinese college students. Based on these concerns, this study aimed to examine whether physical literacy could be used to predict the physical activity behaviors of Chinese university students in order to provide an efficient tool for encouraging public health in higher educational institutions. Additionally, this study also intended to examine the effectiveness of the logistic regression algorithm with machine learning techniques in the field of social science since there is a lack of studies focused on machine learning techniques in the field. The following hypotheses were examined:

Ha1: PL measured by intrinsic motivation, sense of self and self-confidence, self-expression and communication with others, and knowledge and understanding is statistically significant and positively correlates with PA behavior.

Ha2: PA behavior can be predicted by a linear combination of the independent variables of physical literacy measured by intrinsic motivation, sense of self and self-confidence, self-expression and communication with others, knowledge and understanding, age and gender.

Methods

Participants

A cross-sectional survey design was adopted for this study. Convenience sampling was used to collect research data in six cities in mainland China, which were Bei Jing, Tian Jin, Xi'an, Huai Nan, Chong Qing, and Nan Jing. A total of 1,591 Chinese university students (female = 813 and male = 778) with a mean age of 19.63 (*SD* = 1.36) from 12 universities were included in this research. All participants' informed consent forms were obtained, and this study was approved by an Institutional Review Board.

Measures

The *Behavioural Regulation in Exercise Questionnaire (BREQ-3)* comprised 24 items with a 5-point Likert-type response scale – ranging from 'not true for me' to 'very true for me' – for measuring behavioral regulation toward exercise contexts based on the continuum theoretical framework of self-determination was used for data collection (Markland & Tobin, 2004; Wilson et al., 2006). Additionally, the 24 items were divided into six subscales: amotivation, external regulation, introjected regulation, identified regulation, integrated regulation, and intrinsic regulation. The subscale of intrinsic regulation, which consists of 4 items, was adopted by this study to measure Chinese university students' intrinsic motivation and an excellent internal consistency was found (Cronbach's $\alpha = .94$).

The *Perceived Physical Literacy Instrument* (PPLI), developed by Sum et al. (2016), was used to examine the level of Chinese university students' physical literacy. The PPLI is comprised of 9 items with a 5-point Likert scale with 3 items each for three subscales. There are good internal consistencies for the three subscales, Cronbach's α of .79 for knowledge and understanding, Cronbach's α of .78 for self-expression and communication with others and Cronbach's α of .83 for sense of self and self-confidence.

Furthermore, this study used four items from the *International Physical Activity Questions Short Form* (IPAQ-SF) instrument, which indicated acceptable reliability and validity for collecting information about individuals' PA levels over the last 7 days (Craig et al., 2003; Macfarlane et al., 2007), to determine the total amount of moderate and vigorous-intensity PA time that was spent by Chinese university students over a seven-day period.

Procedure

12 college professors who currently working for universities in China were contacted to request their cooperation in recruiting participants from their institutions after receiving approval to conduct the research from the Institutional Review Board (IRB). These 12 college professors work in different cities in China: Bei Jing, Tian Jin, Xi'an, Huai Nan, Chong Qing, and Nan Jing. After consenting in recruiting participants, each college professor received an online survey link to share in their classes, and potential participants would then be able to access the online survey through the link. Once participants clicked on the link, they would first be presented with an informed consent form on the first page of the survey for them to read and click, acknowledging that they gave consent to participate in the survey. After consent was granted, the potential participants would then continue answering the survey questions.

Data Analysis

A logistic regression model (LRM) was utilized to examine whether PL can be used to predict the PA behavior of Chinese university students. The Pearson correlation test was conducted to examine the relationship between variables of PA behavior, age, gender, intrinsic motivation, sense of self and self-confidence, knowledge and understanding, and self-expression and communication with others. In addition, a logistic regression algorithm was used to investigate a proposed model that could be a useful practical model to predict Chinese university students' PA behaviors. According to Lee (2005), the logistic regression with maximum likelihood estimation is a sophisticated technique to examine the probability with a combination of continuous and categorical predictors for a binary categorical outcome variable. Additionally, the logistic regression does not require an assumption of normality (Lee, 2005).

Several steps must be followed to conduct and evaluate an LRM. First, the dataset of the study was randomly split into train and test datasets. The train dataset was used to build an LRM, and the test dataset was used to examine the accuracy of the LRM. Second, the confusion matrix was conducted to examine the accuracy of actual values and predicted values for the LRM, and the formula of the confusion matrix is provided in Table 1. Third, the Receiver operating characteristic (ROC) curve was plotted to examine the discriminatory ability of the LRM by accurately identifying PI and PA behaviors among the participants (Kumar & Indrayan, 2011).

Table I
Confusion Matrix of the Logistic Regression Model

	Predicted: PI	**Predicted: PA**
Actual PI	PI (True Positive)	PA (False Negative)
Actual PA	PI (False Positive)	PA (True Negative)
Accuracy =	True Positive + True Negative	
	True Positive + False Positive + False Negative + True Negative	

Fourth, a Concordance (C-statistic) test, which is a measurement of goodness of fit for binary outcome LRM, was used to investigate the ability of the discrimination of the LRM, but the C-statistic did not examine the predictiveness of the accuracy of the LRM (Pencina & D'Agostino, 2015). Additionally, the range of the values for the C-statistic is generally from 0.5 to 1 and the higher the value of the C-statistic indicates a better model. The R package of *caret* conducted by Kuhn (2008) was used to conduct the statistical analyses. To determine statistical significance, an alpha of 0.5 was used.

Findings

Summary Statistics

According to the WHO (2010), it is suggested that adults 18 to 64 years of age should participate in moderate-intensity aerobic PA for at least 150 minutes or vigorous-intensity aerobic PA for at least 75 minutes, or an equiv-

Table II
Descriptive Statistics and Correlation Matrix (N = 1,591)

	im	**ku**	**se**	**ssc**	**age**	**vpw**	**mpw**
im	-						
ku	0.72***	-					
se	0.59***	0.53***	-				
ssc	0.64***	0.65***	0.68***	-			
age	0.02	-0.03	0.05*	0.06*	-		
vpw	0.30***	0.22***	0.19***	0.25***	-0.15***	-	
mpw	0.23***	0.18***	0.16***	0.19***	-0.17***	0.33***	-
M	14.715	12.045	10.082	10.081	19.631	59.689	69.136
SD	3.609	2.271	2.532	2.659	1.361	74.900	82.064
minimum	4	3	3	3	18	0	0
maximum	20	15	15	15	23	360	420
range	16	12	12	12	5	360	420
skewness	-0.309	-0.548	0.097	-0.002	0.516	1.764	1.807
kurtosis	-0.262	0.181	-0.239	-0.298	-0.640	3.218	3.741

Note. *p < 0.05, **p < 0.01, and ***p < 0.001. ku = knowledge and understanding, ssc = sense of self and self-confidence, se = self-expression and communication with others, im = intrinsic motivation, skew = skewness, kurt = kurtosis, vpw = vigorous-intensity aerobic physical activity time per week, mpw = moderate-intensity aerobic physical activity per week. The same hereinafter.

alent combination of the moderate- and vigorous-intensity aerobic PA time during a week to benefit their physical fitness. A mean value of 59.689 (*SD* = 74.900) was found for the vigorous-intensity aerobic PA minutes per week with the total sample of 1,591, as displayed in Table 2, and 476 out of 1,591 participants participated in vigorous-intensity PA equal or more than 75 minutes during the week prior to completing the survey. Moreover, a mean value of 69.136 (*SD* = 82.064) was found for moderate-intensity aerobic PA minutes per week with the total sample of 1,591, and 229 out of 1,591 participants participated in moderate-intensity PA equal or more than 150 minutes during the week prior to completing the survey.

Pearson's correlation was used to examine the correlations among the variables, and the results indicated that vigorous and moderate-intensity aerobic PA per week had a positive weak association with intrinsic motivation, knowledge and understanding, sense of self and self-confidence, and self-expression and

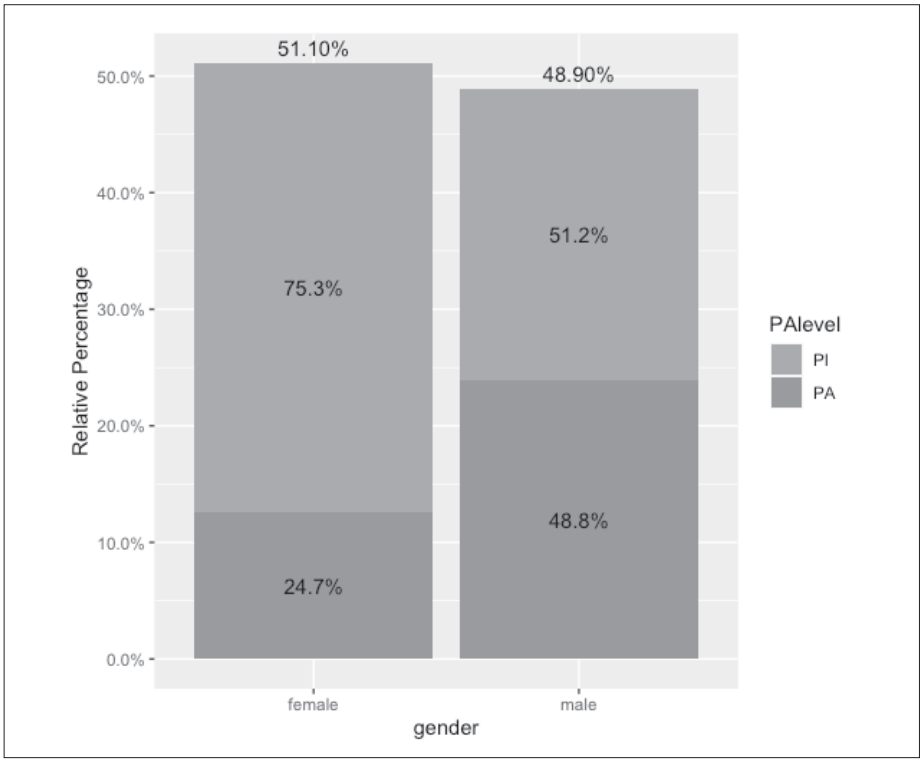

Fig. 1. - *The relative percentages of PA behavior for gender groups.*

communication with others. On the other hand, vigorous and moderate-intensity aerobic PA per week had a negative weak association with age.

According to suggestions from the WHO (2010), the cut-off PA time for moderate-intensity PA was 150 minutes and for vigorous-intensity aerobic PA was 75 minutes. After combining the results of those who met the recommendation of the moderate and vigorous-intensity aerobic PA, 1,010 out of 1,591 participants participated in PA less than the suggested, and the 1,010 participants were coded as PI in comparison to 581 out of 1,591 coded as PA in a binary categorical variable of "PAlevel" (physical inactivity = 0, physical activity = 1). Moreover, the differences of PA behavior between gender and age were given in Figure 1 and Figure 2.

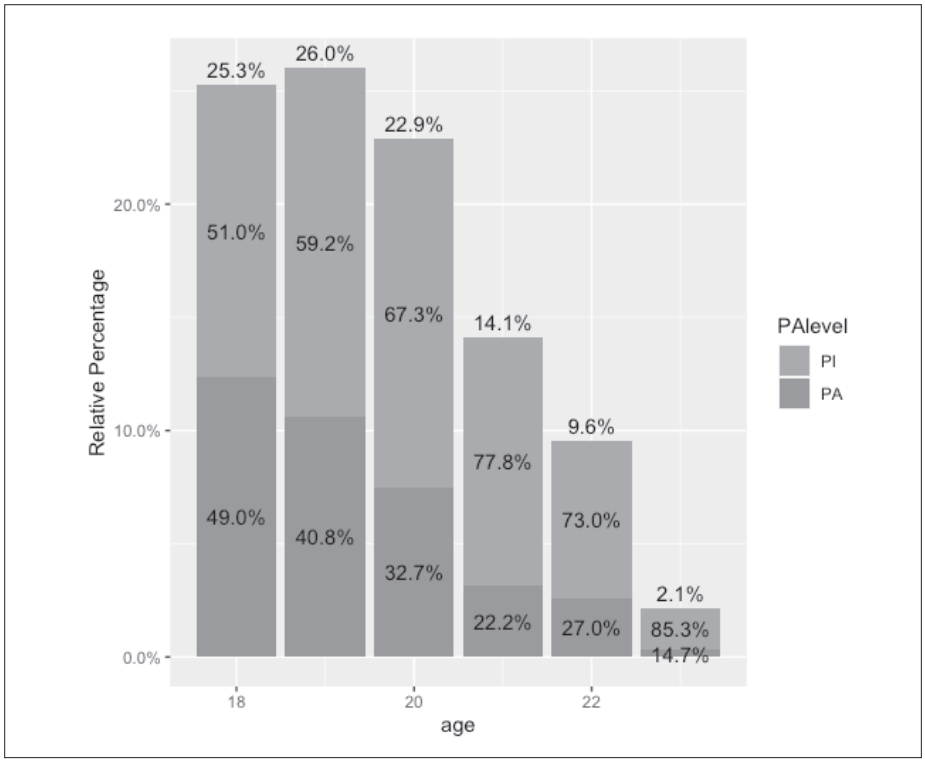

Fig. 2. - *The relative percentages of PA behavior among age groups.*

Evaluation of the Logistic Regression Model

The total dataset (N = 1,591) was randomly split into train and test datasets with a ratio of 70%-30%, suggested by Dangeti (2017). The train dataset (N = 1114) was used to build up a binary LRM and the test dataset (N = 477) was used to evaluate the effectiveness of the LRM. The LRM was initially examined with six independent variables (IVs) of age, gender, intrinsic motivation, sense of self and self-confidence, knowledge and understanding, and self-expression and communication with others. However, the two IVs of knowledge and understanding and self-expression and communication with others were not statistically significant predictors. Hence the two IVs were removed from the LRM model. After the reduction of the two non-statistically significant predictors, the LRM consisted of 4 IVs. The result of the LRM is presented in Table 3. Moreover, the null deviance of the LRM was 1462.5 with a degree of freedom of 1113 for the intercept. After adding to the four predictors, the deviance reduced to 1271.7, losing 4 degrees of freedom from null deviance to residual deviance. Additionally, a Chi-square analysis was conducted to examine the deviance changes between the null deviance and residual deviance and the result indicated a statistically significant reduction of the deviance ($p<.001$). Moreover, there are no concerns for multicollinearity due to the maximum magnitude variance inflation factor value of the 4 predictors which was 1.646, suggested by Field et al. (2012). Furthermore, based on the estimation of odds ratio for PA behavior, PA was 2.655 times higher when gender (from female to male) was involved; PA was 1.144 times higher when intrinsic motivation was involved; while PA was 1.091 times

Table III
Results of Logistic Regression Model with Train Dataset

DVs	b	SE	95% CI		t	VIF	OR (95% CI)
Intercept	2.456	1.008	0.490	4.443	2.438*		11.661 (1.633, 85.047)
gender(male)	0.976	0.138	0.708	1.249	7.077***	1.014	2.655 (2.029, 3.486)
age	-0.330	0.052	-0.433	-0.229	-6.355***	1.042	0.719 (0.649, 0.795)
im	0.135	0.026	0.085	0.186	5.219***	1.635	1.144 (1.088, 1.204)
ssc	0.088	0.034	0.022	0.155	2.602**	1.646	1.091 (1.022, 1.167)

Note. Null deviance (df =1113) = 1462.5, Residual deviance (df =1109) = 1271.7, AIC (Akaike information criterion) = 1281.7, log likelihood (df=5) = -635.9, b = unstandardized regression coefficients, VIF = variance inflation factor, t = t-value, and OR = odds ratio.

higher when sense of self and self-confidence was involved. On the other hand, PA was 0.719 times lower when age (from young to old) was involved.

The results indicated that the three IVs of gender, intrinsic motivation and sense of self and self-confidence were statistically significantly positively associated with PA behavior. On the other hand, the IV of age was statistically significantly negatively associated with PA behavior. The results illustrated that for every 1 raw score unit increase in intrinsic motivation and sense of self and self-confidence there was an associated increase of .135 and .088 logit odds of PA behavior. Additionally, changing from female to male was associated with an increase in 0.976 logit odds of PA behavior. In contrast, for every 1-year increase in age, it was associated with a decrease in .330 logit odds of PA behavior.

The test dataset ($N = 477$) was used to evaluate the accuracy of the LRM. A Confusion Matrix was used to examine the performance of the LRM, and the result of accuracy on the confusion matrix for LRM was .715 (95% CI [.672, .755]) indicating that the prediction accuracy of the LRM was 71.5%, as displayed in Table 4. Additionally, the accuracy of the LRM was statistically significantly higher than the accuracy value of .635 for the No Information Rate that indicated the largest proportion of the DV with a majority of PI ($p < .001$), and it indicated that the four IVs increased the accuracy of the LRM.

Meanwhile, a ROC curve was plotted to illustrate the performance of the LRM to distinguish between the true positive rate (TPR) and false positive rate (FPR). The results showed that the ROC curve was from the diagonal line to the left-top area of TPR, which indicated a good discriminatory ability for distinguishing between TPR and FPR, as displayed in Figure 3. Accord-

TABLE 4
Confusion Matrix for the Logistic Regression Model

Dataset	Reference	Prediction		Sensitivity	Specificity	Accuracy (95% CI)
		PI	PA			
Test dataset	PI	258	91	.852	.477	.715 (.672, .755)
	PA	45	83			
Train dataset	PI	592	230	.837	.435	.690 (.662, .717)
	PA	115	177			
20-fold	PI	52.3%	19.8%	.834 (*SD* = .058)	.469 (*SD* = .075)	.698
	PA	10.5%	17.5%			

ing to Hajian-Tilaki (2013), the value of the Area Under the Curve (AUC) was used to examine the inherent validity of the LRM by combining the measures of TPR and FPR. The result of the AUC value was .767 (95% CI [.725, .809]), which indicated that 76.7% of the PA behaviors, including PA and PI, among the participants could be distinguished by the LRM, and the LRM indicated a small discriminatory power which is clinically useful, which is higher than .75, suggested by Fan et al. (2006). Moreover, the result of the C-statistic test was .767, which was consistent with the value of the AUC (Pencina & D'Agostino, 2015). According to Dangeti (2017), the result of the C-statistic indicated that this LRM is a good model, it is higher than .70.

Furthermore, according to the suggestion of Dangeti (2017), a randomly generated 20-fold cross-validation technique was used to examine the accuracy of the predictiveness of the LRM. Based on the 20-fold cross-validation technique, the total dataset (N = 1,591) was split into 20 datasets randomly and equally, and the LRM was validated 20 times with each of the 20 datasets. The result of the 20-fold cross-validation for ROC value was .744 (SD = .045). The results are presented in Table 4.

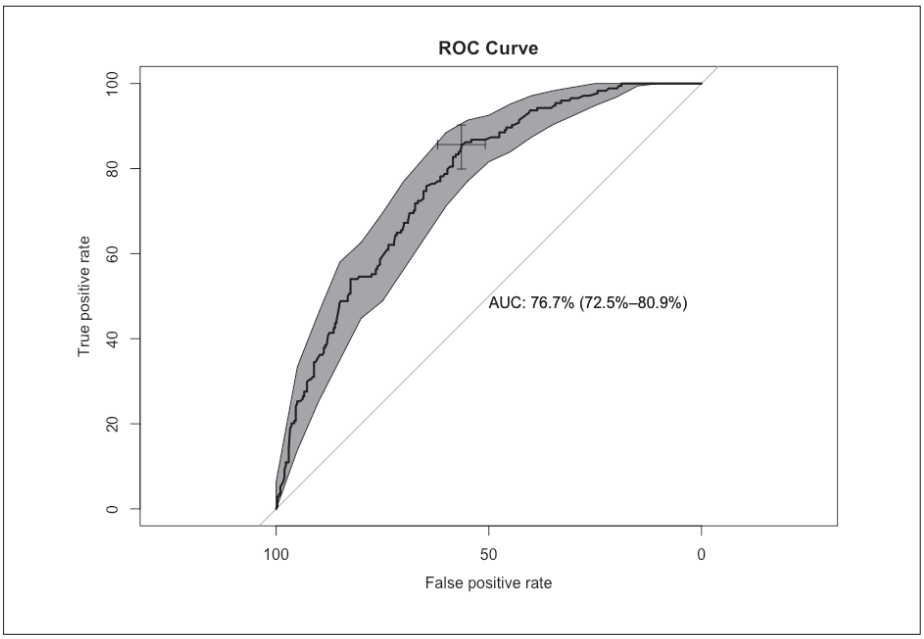

Fig. 3 - *Receiver operating characteristic curve with test dataset.*

Discussion

This study found a practical binary machine learning LRM, comprised of 4 statistically significant predictors: gender, age, intrinsic motivation and sense of self and self-confidence, that could be used to predict Chinese university students' PA behaviors. Based on the results of the confusion matrix, the accuracy of our LRM was .715, indicating that 71.5% of the PA behaviors of participants could be predicted by the LRM. In addition, the LRM has demonstrated a good discriminatory ability for distinguishing between TPR and FPR based on the results of the ROC curve. Similarly, the LRM in this study indicated a good model as the C-statistic value was 76.6, a good measure as suggested by Dangeti (2017).

The findings of this research are consistent with a study conducted by Haase et al. (2004), who found that gender was a statistically significant predictor of university students' PA behaviors across 23 countries. The present study's LRM and Haase's LRM potentially illustrate that male students might be more active in PA than female students at the university level. The empirical findings are also supported by studies conducted by Dumith et al. (2011) and Althoff et al. (2017) who found that males were more engaged in PA than females worldwide. Hence, this may be more crucial support for cultivating female students' participation in PA and promoting the benefits of healthy physical activity development on university campuses.

On the other hand, a discrepancy can be noted between the present study's LRM and Haase's LRM, which is that age is not a statistically significant predictor in Haase's LRM model. This perceived discrepancy may be due to the fact that the participants of the present study were more homogeneous with respect to age than those in Haase's study. In contrast, the present study was consistent with the study by Pengpid et al. (2015), who indicated that age was a significant predictor for PA behavior in their LRM with university students from 23 counties. In addition, in their study, there was a decrease in the odds ratio associated between increasing age and PA (Pengpid et al., 2015). The findings may be interpreted as indicating that the older students are less likely to participate in PA than younger students on university campuses. Additionally, the negative association between increasing age and PA has also been found in the middle-to-older-adult population worldwide (Hallal et al., 2012). The result may offer statistical evidence for the importance of fostering individuals' life-long PA behaviors in order to promote an increased quality of living in higher education institutions.

Furthermore, the present LRM included the two statistically significant PL indicators of intrinsic motivation and sense of self and self-confidence,

which were positively associated with the odds ratio of PA. The results indicate that students who experience higher levels of intrinsic motivation and sense of self and self-confidence are more likely to participate in PA. The results are also consistent with the study conducted by Ma et al. (2020), who investigated a relationship between PL and PA among Chinese university students. Ma et al. (2020) found that motivation and confidence were significant predictors for predicting Chinese university students' PA levels in their multiple regression model with an adjusted R^2 value of .120. Likewise, Choi et al. (2018) also found that confidence was one of the significant predictors of PA behavior among adolescents in Hong Kong through their multiple regression model with an adjusted R^2 value of .052. Although the two studies offered statistically significant multiple regression models to illustrate the significant positive association between motivation and confidence and PA behavior, the adjusted R^2 values for the two studies were relatively low. In order to extend the applicability of information on the influences on the PA behavior of the individual, the present LRM could build empirical evidence to support the idea that motivation and confidence might play an essential role in increasing higher levels of PA participation. Furthermore, the findings of this study also offer statistical support for the theory of PL, promoted by Whitehead (2010), suggesting that the affective domain of motivation and confidence can grow individuals' PA behaviors and ultimately promote lifelong PA participation.

Moreover, the two IVs of knowledge and understanding and self-expression and communication with others were not found to be significant predictors of PA behavior in the present LRM. The findings of this present study are inconsistent with another study conducted by Choi et al. (2018), who found that knowledge and understanding and self-expression and communication with others were significant predictors of PA behavior in their multiple regression analyses. However, the findings of this study are consistent with the study conducted by Haase et al. (2004) who found in their LRM that knowledge and understanding was not a significant predictor of PA behavior among university student populations from 23 counties. According to Longmuir and Tremblay (2016), concern about the process of measuring PL may differ by culture and age, and further investigation is needed. Based on the concern, the contradictory findings between the present study, and the studies by Haase et al. (2004) and Choi et al. (2018) might be due to the differences in physical education curriculum designs, implementation in different locations and cultures, and the age of participants. Another reason may be that our study and that of Haase et al. (2004) examined university students' PA behavior, and differs from Choi et al. (2018), who investigated

the PA behaviors in the adolescent population. In addition, the construct of the PPLI instrument, which was used in the present study and Choi et al.'s study, was based on the literature review of PL theories and interviews of Hong Kong Chinese physical education teachers (Sum et al., 2016). It could be assumed that the PPLI instrument was based on the Hong Kong physical education curriculum and that university students in mainland China may not have the same understanding as students in Hong Kong. The present study may offer empirical support for the concern as indicated by Longmuir and Tremblay (2016) that different curriculum designs and ages may cause a discrepancy in measuring individuals' PL.

Limitations and Conclusion

One of the limitations of this study is that the university students' PA behavior may be subjective as the present study used a self-report instrument to measure their PA behavior. Although self-report information about PA behavior has been widely used, it may produce a difference in the results of the actual PA behavior. Further studies need to examine the present LRM with multiple tools to collect participants' PA behavior. Another limitation is that the present study may not be used to imply a causal relationship between the variables of intrinsic motivation, sense of self and self-confidence, age, gender and PA behavior, as the present study used a cross-sectional design, even though the present study found significant associations between the variables. A future study may conduct an intervention design to study potential causal relationships among the variables.

This study offers a practical LRM that can be used to predict Chinese university students' PA behavior. The results of the confusion matrix indicate that the accuracy of the LRM was .715, which illustrated that 71.5% of Chinese university students' PA behavior can be predicted by the combination of IVs, intrinsic motivation, sense of self and self-confidence, age and gender. The present LRM can be a useful tool for higher education institutions to monitor and foster students' PA behavior in order to cultivate a healthy lifestyle and lifelong participation in PA. Of note also, this study might be the first study to use a machine learning logistic regression algorithm to examine PL as a contributory factor for predicting PA behavior among university students in the social sciences. The results of the present study support that using a machine learning logistic regression algorithm is a valid technique to evaluate a prediction model in the social and educational sciences.

Funding: This research received no external funding.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy and ethical concerns.

Conflicts of Interest: The authors declare no conflict of interest.

Declaration of Interest: There is no financial/personal interest or belief that could affect our objectivity.

REFERENCES

Althoff, T., Sosič, R., Hicks, J.L., King, A.C., Delp, S.L., & Leskovec, J. (2017). Large-scale physical activity data reveal worldwide activity inequality. *Nature, 547*(7663), 336-339. https://doi.org/10.1038/nature23018

Cairney, J., Dudley, D., Kwan, M., Bulten, R., & Kriellaars, D. (2019). Physical literacy, physical activity and health: Toward an evidence-informed conceptual model. *Sports Medicine, 49*(3), 371-383. https://doi.org/10.1007/s40279-019-01063-3

Caldwell, H.A.T., Di Cristofaro, N.A., Cairney, J., Bray, S.R., MacDonald, M.J., & Timmons, B.W. (2020). Physical literacy, physical activity, and health indicators in school-age children. *International Journal of Environmental Research and Public Health, 17*(15), Article 5376. https://doi.org/10.3390/ijerph17155367

Castelli, D.M., Barcelona, J.M., & Bryant, L. (2015). Contextualizing physical literacy in the school environment: *The challenges. Journal of Sport and Health Science, 4*(2), 156-163. https://doi.org/10.1016/j.jshs.2015.04.003

Chen, A. (2015). Operationalizing physical literacy for learners: Embodying the motivation to move. *Journal of Sport and Health Science, 4*(2), 125-131. https://doi.org/ 10.1016/j.jshs.2015.03.005

Chen, X., Cui, J., Zhang, Y., Peng, W. (2020). The association between BMI and health-related physical fitness among Chinese college students: A cross-sectional study. *BMC Public Health*, *20*(1), Article number 444. https://doi.org/10.1186/s12889-020-08517-8

Choi, S.M., Sum, R.K.W., Leung, F.L.E., & Ng, R.S.K. (2018). Relationship between perceived physical literacy and physical activity levels among Hong Kong adolescents. *PloS One, 13*(8), Article e0203105. https://doi.org/10.1371/journal.pone.0203105

Craig, C.L., Marshall, A.L., Sjöström, M., Bauman, A.E., Booth, M.L., Ainsworth, B.E., Pratt, M., Ekelund, U., Yngve, A., Sallis, J.F., & Oja, P. (2003). International physical activity questionnaire: 12-country reliability and validity. *Medicine and Science in Sports and Exercise, 35*(8), 1381-1395. https://doi.org/10.1249/01.MSS.0000078924.61453.FB

Dangeti, P. (2017). *Statistics for Machine Learning: Techniques for Exploring Supervised, Unsupervised, and Reinforcement Learning Models with Python and R.* Packet Publishing.

Dudley, D.A. (2015). A Conceptual model of observed physical literacy. *The Physical Educator, 72*(5), 236-260. https://doi.org/10.18666/TPE-2015-V72-I5-6020

Dumith, S.C., Hallal, P.C., Reis, R.S., & Kohl, H.W., 3rd (2011). Worldwide prevalence of physical inactivity and its association with human development index in 76 countries. *Preventive Medicine, 53*(1-2), 24-28. https://doi.org/10.1016/j.ypmed.2011.02.017

Edwards, L.C., Bryant, A.S., Keegan, R.J., Morgan, K., & Jones, A.M. (2017). Definitions, foundations and associations of physical literacy: A systematic review. *Sports Medicine, 47*(1), 113-126. https://doi.org/10.1007/s40279-016-0560-7

Fan, J., Upadhye, S., & Worster, A. (2006). Understanding receiver operating characteristic (ROC) curves. *CJEM, 8*(1), 19-20. https://doi.org/10.1017/S1481803500013336

Field, A., Miles J.N.V., & Field, Z. (2012). *Discovering statistics using R*. London: Sage.

Giblin, S., Collins, D., & Button, C. (2014). Physical literacy: Importance, assessment and

future directions. *Sports Medicine, 44*, 1177-1184. https://doi.org/10.1007/s40279-014-0205-7

Guthold, R., Ono, T., Strong, K.L., Chatterji, S., & Morabia, A. (2008). Worldwide variability in physical inactivity a 51-country survey. *American Journal of Preventive Medicine, 34*(6), 486-494. https://doi.org/10.1016/j.amepre.2008.02.013

Guthold, R., Stevens, G.A., Riley, L.M., & Bull, F.C. (2020). Global trends in insufficient physical activity among adolescents: A pooled analysis of 298 population-based surveys with 1.6 million participants. *The Lancet Child & Adolescent Health, 4*(1), 23-35. https://doi.org/10.1016/s2352-4642(19)30323-2

Haase, A., Steptoe, A., Sallis, J.F., & Wardle, J. (2004). Leisure-time physical activity in university students from 23 countries: Associations with health beliefs, risk awareness, and national economic development. *Preventive Medicine, 39*(1), 182-190. https://doi.org/10.1016/j.ypmed.2004.01.028

Hajian-Tilaki K. (2013). Receiver Operating Characteristic (ROC) Curve Analysis for Medical Diagnostic Test Evaluation. *Caspian Journal of Internal Medicine, 4*(2), 627-635.

Hallal, P.C., Andersen, L.B., Bull, F.C., Guthold, R., Haskell, W., Ekelund, U., & Lancet Physical Activity Series Working Group (2012). Global physical activity levels: Surveillance progress, pitfalls, and prospects. *Lancet, 380*(9838), 247-257. https://doi.org/10.1016/S0140-6736(12)60646-1

Keegan, R., Keegan, S., Daley, S., Ordway, C., & Edwards, A. (2013). *Getting Australia Moving: Establishing a Physically Literate Active Nation (Game Plan)*. University of Canberra.

Kuhn, M. (2008). Building predictive models in R using the caret package. *Journal of Statistical Software, 28*(5), 1-26. http://dx.doi.org/10.18637/jss.v028.i05

Kumar, R., & Indrayan, A. (2011). Receiver operating characteristic (ROC) curve for medical researchers. *Indian Pediatrics, 48*(4), 277–287. https://doi.org/10.1007/s13312-011-0055-4

Lee, S. (2005). Application of logistic regression model and its validation for landslide susceptibility mapping using GIS and remote sensing data journals. *International Journal of Remote Sensing, 26*(7), 1477-1491. https://doi.org/10.1080/01431160412331331012

Longmuir, P.E., & Tremblay, M.S. (2016). Top 10 research questions related to physical literacy. *Research Quarterly for Exercise and Sport, 87*(1), 28–35. https://doi.org/10.1080/02701367.2016.1124671

Macfarlane, D.J., Lee, C.C.Y., Ho, E.Y.K., Chan, K.L., Chan, D.T.S. (2007). Reliability and validity of the Chinese version of IPAQ (short, last 7 days). *Journal of Science and Medicine in Sport, 10*(1), 45-51. https://doi.org/10.1016/j.jsams.2006.05.003

Ma, R.S., Sum, R.K.W., Li, M.H., Huang, Y., & Niu, X.L. (2020). Association between physical literacy and physical activity: A multilevel analysis study among Chinese undergraduates. *International Journal of Environmental Research and Public Health, 17*(21), Article 7874. https://doi.org/10.3390/ijerph17217874

Markland, D., & Tobin, V. (2004). A modification to the behavioral regulation in exercise questionnaire to include an assessment of amotivation. *Journal of Sport & Exercise Psychology, 26*(2), 191-196. https://doi.org/10.1123/jsep.26.2.191

Pencina, M.J., & D'Agostino, R.B., Sr (2015). Evaluating Discrimination of Risk Prediction Models: The C Statistic. *JAMA, 314*(10), 1063-1064. https://doi.org/10.1001/jama.2015.11082

Pengpid, S., Peltzer, K., Kassean, H. K., Tsala Tsala, J.P., Sychareun, V., & Müller-Riemenschneider, F. (2015). Physical inactivity and associated factors among university students in 23 low-, middle- and high-income countries. *International Journal of Public Health, 60*(5), 539-549. https://doi.org/10.1007/s00038-015-0680-0

SHAPE America (2014). *National Standards & Grade-Level Outcomes For K-12 Physical Education.* Champaign, IL: Human Kinetics.

Shearer, C., Goss, H. R., Boddy, L. M., Knowles, Z. R., Durden-myers, E.J., & Foweather, L. (2021). Assessments related to the physical affective and cognitive domains of physical literacy amongst children aged 7-11.9 years: A systematic review. *Sports Medicine - Open, 7*(1), Article 37. https://doi.org/10.1186/s40798-021-00324-8

Sum, R.K.W., Ha, A.S.C., Cheng, C.F., Chung, P.K., Yiu, K.T.C., Kuo, C.C., … Wang, F.J. (2016). Construction and validation of a Perceived Physical Literacy Instrument for physical education teachers. *PLoS One, 11*(5), Article e0155610. https://doi.org/10.1371/journal.pone.0155610

Sum, R.K.W., & Whitehead, M. (2021). Getting up close with Taoist: Chinese perspectives on physical literacy. *Prospects, 50*(2), 141-150. https://doi.org/10.1007/s11125-020-09479-w

Warburton, D.E., Nicol, C.W., & Bredin, S.S. (2006). Health benefits of physical activity: the evidence. *CMAJ: Canadian Medical Association Journal = Journal de l'Association Medicale Canadienne, 174*(6), 801-809. https://doi.org/10.1503/cmaj.051351

Whitehead, M. (2001). The Concept of physical literacy. *European Journal of Physical Education, 6*(2), 127-138. https://doi.org/10.1080/1740898010060205

Whitehead, M. (2010). *Physical literacy: Throughout the life course.* Routledge.

Wilson, P., Rogers, W., Rodgers, W., & Wild, T. (2006). The psychological need satisfaction in exercise scale. *Journal of Sport and Exercise psychology, 28*(3), 231-251. https://doi.org/10.1123/jsep.28.3.231

World Health Organization (2010). *Global Recommendations on Physical Activity for Health*. Geneva, Switzerland.

World Health Organization (2018). *Global Action Plan on Physical Activity 2018-2030: More Active People for a Healthier World*. Geneva, Switzerland.

Manuscript submitted August 2022. Accepted for publication November 2022.