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# Relationships Between Perceived Usefulness and Fitness Wearable Technology User Adoption Mediated by Culture, Gender, and COVID-19: A Meta-Analysis

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**Abstract**
With COVID-19 raging and individuals exercising at home, the adoption of fitness wearable technology (FWT) that help people monitor their physical state has become a pressing matter. Here, we try to bridge the gap that no researcher has examined the link between perceived usefulness (PU) and FWT adoption by using meta-analysis to comprehend the detailed numerical values and moderating factors affecting the relationship. A total of 24 articles with 7180 re-pendants were investigated from January 1, 2015 to March 1, 2022 A.D, producing significant results as follows: (1) There is publication bias in relevant research, and sensitivity analysis suggests that PU influences FWT adoption positively; (2) Subgroup test and regression analysis suggested that cultural background, gender, and COVID-19 can deepen this relationship to varying degrees. More precisely, female (r=0.669) have a greater impact on FWT adoption than men (r=0.658). In addition, users in other countries (r=0.670) are more concerned about PU than Chinese users (r=0.658). Regression analysis showed that after the COVID-19 outbreak, the coefficient (r=0.762) of PU on FWT adoption increased significantly, indicating that people need FWT-assisted exercise to understand and maintain their own physical fitness. The research opens up new ideas for different governments and scholars to promote mass fitness and public health during the COVID-19, providing a reference for the scientific research and development of PU and marketing promotion of the related enterprises' FWT.
**Keywords:** fitness wearable technology; perceived usefulness; adoption; COVID-19; health &fitness; public health

## 1. Introduction

With the rapid development of mobile Internet and digital intelligence, and the con-tinuous enhancement of public fitness awareness, fitness wearable technology (FWT) has gradually become major and active in markets. According to the " Global Fitness Trends Survey Report " compiled by the American College of Sports Medicine (ACSM), wearable technology ranks first among the top 20 fitness trends in 2019, and also list in second in 2020. It can be seen that FWT such as sports watches, bracelets, fitness trackers, smart running shoes, smart clothing and running wearable devices based on motion capture technology is accepted by the public. Previous observations suggested that perceived use-fulness (hereinafter referred to as PU) have an effect on user's adoption of wearable devices in early TAM and TPB models (Wang et al., 2018). However, none of the authors used meta-analytical techniques to determine detailed numerical values to examine the link between PU and FWT adoption. In existing studies on various wearable devices, the correlation coefficient between PU and adoption varies significantly from 0.169 (Zhang, 2021) to 0.788 to 0.788 (Cheung, 2021). The possible fac-tors that inconsistency cannot be ruled out variances in study equipment, gender, out-break of COVID-19, limitations in nations, locations and so on. Therefore, we need to ask the following questions: (1) What is the relationship between the PU of FWT users and their adoption? (2) Is it mediated by cultural background, gender, and COVID-19? These studies will provide new insight into the relationship between PU and adoption.

Perceived usefulness refers to an individual's subjective perception that when adopt-ing a new product or new technology, may increase its work utility. The traditional tech-nology acceptance model points out that PU is the process of user perception (Davis, 1989). It can al-so refer to the consumer's expectation that the product will improve the quality of life and improve the degree of work performance (Wei, 2005). Firstly, many scholars used some theoretical models to analyze the PU, such as using the push-pull theory and TAM model to analyze the PU of health wearable devices from the three dimensions of information acquisition, social interaction and leisure fashion motivation(Yang, 2016; Wu et al., 2017; Kim and Chiu, 2019; Talukder et al., 2019; Binyamin, 2020). Secondly, recent research found that as FWT become more functional, their PU increases, providing a huge opportunity to easily collect and study health data (Canhoto et al., 2017; Sergueeva et al., 2020; Pancar,2021). Therefore, the study can provide a reference for improving the function of FWT and enhancing the user's perceived usefulness.

Adoption refers to the behavior in which users are willing to acquire products or ser-vices (Li, 2022). For example, cloud computing adoption refers to the user's adoption and selec-tion decision of cloud computing services and cloud computing-based applications (Lu and Wang, 2015). The study includes "purchasing, adoption intention, and acceptable" into the indicator "adoption" to FWT. Current models for analyzing adoption include TRA, TAM, MM, TPB, IDT, SCT, TTF, TAM2 and UTAUT model (Tan, 2012; Diao,2010) the relevant research focuses on explor-ing the influencing factors of user adoption in various fields, such as mobile commerce, online consumption, knowledge payment platform, new product, mobile medical, aca-demic apps, online health communities and so on (Jin, 2020; LI et al., 2019; Zhu, 2020; Zhang et al., 2018). We now extend our study to the adoption of FWT, which can be more advantageous or helpful for practitioners, policy-makers, and academic researchers.

Although Talukder et al. (2019)and Tang et al. (2018) has successfully demonstrated and explained PU is one of the factors that affects user adoption few studies have aimed to identify the specific coefficient between the PU and adoption with meta-analysis (Jin ,2020). For some examples, the findings of Chuah et al. (2016) confirm that PU drive attitudes towards smartwatch, which translates into adoption. According to Felea et al. Felea et al. (2015), Lunney et al. Lunney et al. (2016) and Zhao et al. (2018) show that three exogenous variables (PU, perceived enjoyment, and visual ap-peal of wearable devices) exert significant positive effects on adoption. Among them, the coefficients of PU on adoption are: 0.702, 0.410 and 0.6. These examples all demonstrate the numerical value of the relationships between PU and adoption, but the values given vary. Although Wu et al. (2017) used meta-analysis, his conclusions would have been more useful if he had focused on the relationship between PU and FWT adoption in a wider range had been explored. At the same time, the above results did not explore whether oth-er factors affect the relationships. Therefore, we aim to bridge this gap by listing all rele-vant studies and understanding detailed numerical values of PU's influence on adoption of FWT. Furthermore, there would seem to be a definite need for investigating whether cultural background, gender, and COVID-19 modulate relationships of PU and FWT adoption.

## 2. Materials and Methods

### 2.1. The selection process of articles

Meta-analysis is the process of summarizing, evaluating and quantitatively analyzing the collected literature (Wu et al, 2017). It is useful method for the re-statistics of most existing empirical literature results, calculating various statistical indicators according to relevant formulas, and judging the significance of paths by statistical index coefficients. To analyze the research topic of PU and the adoption of FWT users, relevant literatures in various academic databases was collected and retrieved. The retrieval time is from January 1, 2015 to March 1, 2022, with "fitness, wearable devices, fitness wearable devices, FWT, smartwatches, smart glasses, acceptance and adoption" as the keywords, in the Web of Science, Springer, Wiley, SPORT Discus, Science Direct, Google-Scholar, CNKI, and other domestic and foreign databases searched for literature related to the analysis of FWT adoption.

### 2.2. Filter criteria

Combined with the requirements of the Meta-analysis method and the research topic “Usage of PU and FWT users”, the criteria for inclusion in Meta-analysis research are: (1)It must be an empirical research that reports experimental and survey data, with the goal of avoiding purely theoretical analyses and review articles; (2) Variables in the study included PU and adoption, reporting correlations between the two or other measures that could be translated into effect sizes; (3) The sample size is clear; (4) If the user's purpose of using the wearable device includes sports or fitness exercise, it will be included in the meta-analysis study. We included a total of 24 papers by multiple screening (Figure 1).

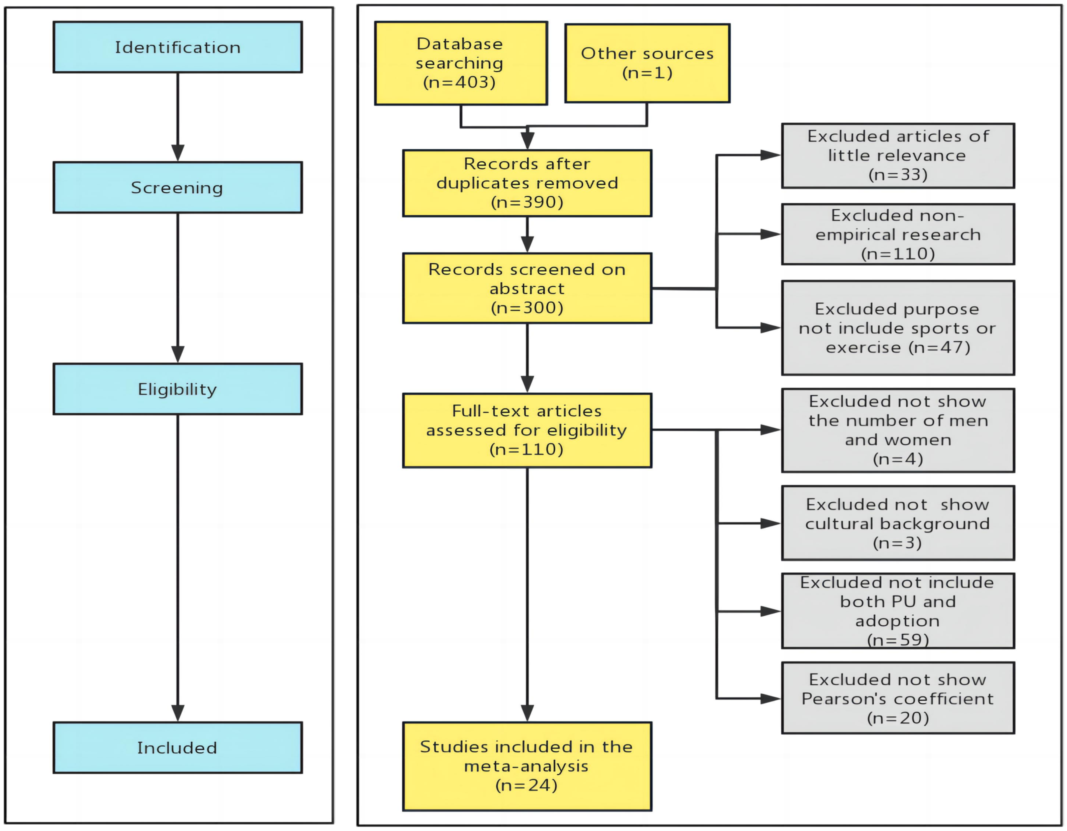


Figure 1. Diagram of the selection of studies

**2.3. Document coding**

The literatures included in the meta-analysis are coded as follows: literature information (the surname of the first author + year of publication), research objects (different types of fitness wearable technology), survey objects (online or offline FWT users), sample size, gender, cultural background (region) and effect size. The literature effect value was coded according to each independent sample, and 2 coders independently coded according to the literature inclusion and exclusion criteria. The coding consistency was 92%, indicating that the literature coding was more effective and accurate. According to the differences between the two coders, the original documents were re-coded to exclude coding errors. Finally, a total of 7180 respondents, Chinese documents and 17 documents in other languages were included in the meta-analysis (Table 1).

Table 1. Basic information included in the meta-analysis studies

| Author (time of publication) | Research object | Investigation method | Sample size | male | Female | Area | Effect size |
|---|---|---|---|---|---|---|---|
| Wang, 2018 | sports bracelet | online | 285 | 249 | 36 | China | 0.266 |
| Zhao, 2018 | Wearable device | online + offline | 356 | 254 | 102 | China | 0.600 |
| Wu, 2017 | Wearable device | online | 488 | 190 | 298 | China | 0.620 |
| Li, 2016 | Wearable device | online | 333 | 161 | 172 | China | 0.252 |
| Gao, 2016 | Wearable device | offline | 145 | 67 | 78 | China | 0.600 |
| Hong, 2017 | smart watch | online | 276 | 144 | 123 | China | 0.507 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Chen, 2020 | sports bracelet | online | 291 | 145 | 146 | China | 0.635 |
| Jiao, 2021 | smart watch | online | 300 | 147 | 153 | China | 0.728 |
| Zhang, 2021 | Wearable device | online | 978 | 727 | 251 | China | 0.169 |
| Cheung, 2019 | Wearable device | online | 237 | 130 | 107 | China | 0.802 |
| Huarng, 2022 | Wearable device | online | 335 | 204 | 131 | China | 0.519 |
| Cheung, 2021 | Wearable device | online | 211 | 119 | 92 | China | 0.788 |
| Zhang, 2017 | Wearable device | online + offline | 436 | 197 | 239 | China | 0.473 |
| Chau, 2019 | Wearable device | online | 171 | 94 | 77 | China | 0.735 |
| Shang, 2019 | sports bracelet | online | 223 | 125 | 98 | South Korea | 0.380 |
| Kim, 2018 | Wearable device | online | 247 | 142 | 105 | South Korea | 0.691 |
| Kim, 2015 | smart watch | online | 363 | 216 | 147 | South Korea | 0.598 |
| CHO, 2018 | Wearable device | online | 248 | 162 | 86 | South Korea | 0.410 |
| Chuah, 2016 | smart watch | offline | 226 | 50 | 176 | Malaysia | 0.670 |
| Shahla, 2019 | Wearable device | online | 178 | 73 | 105 | Malaysia | 0.651 |
| Kao, 2019 | sports bracelet | online | 226 | 116 | 110 | Japan | 0.674 |
| Lunney, 2016 | Wearable device | offline | 206 | 90 | 116 | America | 0.410 |
| Felea, 2021 | Wearable device | online | 192 | 52 | 140 | Romania | 0.702 |
| Ernst, 2016 | smart watch | online | 229 | 77 | 152 | Germany | 0.550 |

**2.4. Meta-analysis process**

**2.4.1. Effect size calculation**

In this study, CMA3.0 (Comprehensive Meta-analysis 3.0) professional software was used for meta-analysis. The Pearson correlation coefficient was used as the effect size to integrate the relationship between "PU and adoption of FWT users". In the coding process, some pieces of literature do not directly report the correlation coefficient between PU and adoption or between its various indicators, but report the F value, t value, or $\chi 2$ value. We adopt the formula from Wang Jie [28]. The formula converts it into the r value. Then the correlation coefficient r value was converted to Fisher-Z value for meta-analysis.

$df = n_1+n_2 - 2$ Eq. (1)

$r = [t^2/(t^2 + df)]1/2$ Eq. (2)

$r = [F/(F + df)]1/2$ Eq. (3)

$r = [\chi^2/(\chi^2 + df)]1/2$ Eq. (4)

2.4.2. Model Selection and Heterogeneity Testing

The random-effects model posits that there is not just a real impact size, but that it fluctuates depending on the study population and research methodology (Borenstein et al., 2009). When different study characteristics will affect the meta-analysis results, it is more scientific and reasonable. Therefore, this study decided to conduct a random-effects model for analysis.

In addition, the rationality of the random effects model selection can further verify by the Heterogeneity test. Heterogeneity test methods mainly include Q test and I2 test. The Q-test is a test based on total variation. The effect sizes are assumed to follow a chi-square distribution. If $p<0.05$, it indicates significant heterogeneity; the I2 test mainly reflects the proportion of the true variation of the effect size in the total variation. According to previous viewpoints, the I2 values of 25%, 50%, and 75% can be regarded as the dividing line of low, medium, and high heterogeneity (Higgins et al, 2003).

2.4.3. Publication bias

Publication bias means that the published research literature does not systematically represent the population of research that has been done in the field (Rothstein, 2015). The most effective way to rule out publication bias is to increase the sample size, as the lack of a representative sample, especially the lack of studies with insignificant or unpublished studies, may affect the reliability of the meta-analysis results. In response to this problem, first, we tried to obtain unpublished literary works in the retrieval stage, and obtained one article in other way. second, in the specific meta-analysis process, we used funnel plots, trim and fill tests, Rosenthal's Classic Fail-safe N to further test for publication bias.

**3. Results**

**3.1. Reliability Analysis Results**

Reliability tests can detect the consistency of data results. First, most of the literature use Cronbach's alpha value and composite reliability as reliability coefficients for analysis. In addition, the reliability coefficient of the statistic in this study is dominated by Cronbach's alpha value, and the reliability distribution of all variables in the literature is between 0.825 and 0.98, indicating that the reliability coefficient is higher in the variables in this study.

**3.2. Publication bias test**

First, we use a forest plot to look at the interval distribution. The results are presented Figure 2, the coefficients between PU and Adoption are distributed between 0 and 1 in the 24 articles. The last row of Figure 2 shows that after statistical analysis of random effects, the relationship between the two is 0.663 under the 95% CI. This result is the most direct evidence that PU significantly affects FWT adoption.

| Statistics for each study | | | Study name | | | | | Relative | Relative |
|---|---|---|---|---|---|---|---|---|---|
| Standard error | Variance | Fisher's Z | | Lower limit | Upper limit | Total | Z-Value | weight | weight |
| 0.060 | 0.004 | 0.273 | Wang, 2018 | 0.156 | 0.389 | 285 | 4.577 | 4.19 | |
| 0.053 | 0.003 | 0.693 | Zhao, 2018 | 0.589 | 0.797 | 356 | 13.023 | 4.23 | |
| 0.045 | 0.002 | 0.725 | Wu, 2017 | 0.636 | 0.814 | 488 | 15.967 | 4.27 | |
| 0.055 | 0.003 | 0.258 | Li, 2016 | 0.150 | 0.365 | 333 | 4.679 | 4.22 | |
| 0.084 | 0.007 | 0.693 | Gao, 2016 | 0.529 | 0.858 | 145 | 8.260 | 4.00 | |
| 0.061 | 0.004 | 0.559 | Hong, 2017 | 0.440 | 0.677 | 276 | 9.231 | 4.18 | |
| 0.059 | 0.003 | 0.750 | Chen, 2020 | 0.634 | 0.865 | 291 | 12.724 | 4.19 | |
| 0.058 | 0.003 | 0.924 | Jiao, 2021 | 0.811 | 1.038 | 300 | 15.932 | 4.20 | |
| 0.032 | 0.001 | 0.171 | Zhang, 2021 | 0.108 | 0.233 | 978 | 5.328 | 4.33 | |
| 0.065 | 0.004 | 1.104 | Cheung, 2019 | 0.976 | 1.232 | 237 | 16.891 | 4.15 | |
| 0.055 | 0.003 | 0.575 | Huarng, 2022 | 0.467 | 0.683 | 335 | 10.476 | 4.22 | |
| 0.069 | 0.005 | 1.066 | Cheung, 2021 | 0.930 | 1.202 | 211 | 15.376 | 4.12 | |
| 0.048 | 0.002 | 0.514 | Zhang, 2017 | 0.420 | 0.608 | 436 | 10.694 | 4.26 | |
| 0.077 | 0.006 | 0.940 | Chau, 2019 | 0.788 | 1.091 | 171 | 12.178 | 4.06 | |
| 0.067 | 0.005 | 0.400 | Shang, 2019 | 0.268 | 0.532 | 223 | 5.934 | 4.13 | |
| 0.064 | 0.004 | 0.850 | Kim, 2018 | 0.724 | 0.975 | 247 | 13.275 | 4.16 | |
| 0.053 | 0.003 | 0.690 | Kim, 2015 | 0.587 | 0.793 | 363 | 13.092 | 4.23 | |
| 0.064 | 0.004 | 0.436 | CHO, 2018 | 0.310 | 0.561 | 248 | 6.818 | 4.16 | |
| 0.067 | 0.004 | 0.811 | Chuah, 2016 | 0.679 | 0.942 | 226 | 12.107 | 4.14 | |
| 0.076 | 0.006 | 0.777 | Shahla, 2019 | 0.629 | 0.925 | 178 | 10.279 | 4.07 | |
| 0.067 | 0.004 | 0.818 | Kao, 2019 | 0.687 | 0.949 | 226 | 12.216 | 4.14 | |
| 0.070 | 0.005 | 0.436 | Lunney, 2016 | 0.298 | 0.573 | 206 | 6.207 | 4.11 | |
| 0.073 | 0.005 | 0.871 | Felea, 2021 | 0.729 | 1.014 | 192 | 11.977 | 4.09 | |
| 0.067 | 0.004 | 0.618 | Ernst,2016 | 0.488 | 0.749 | 229 | 9.296 | 4.14 | |
| 0.056 | 0.003 | 0.663 | | 0.553 | 0.773 | | 11.802 | | |

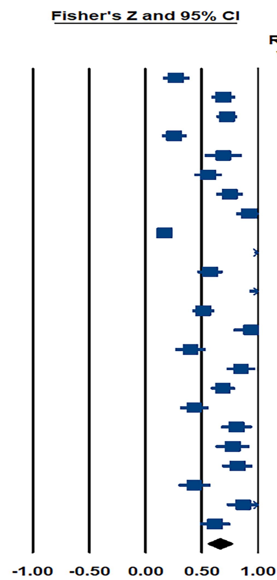


Figure 2. Forest plot

The navy blue box represents the sample size. The larger the sample size, the larger the weight. The distance to the left and right of the line segment represents the 95% confidence interval, and the line segment spans the Y-axis, indicating insignificant. The black diamonds in the bottom row of the figure represent the mean effect sizes and confidence intervals for all studies.

Second, a funnel plot was used to examine publication bias (Figure 3). From the funnel plot, the results of the 24 studies (blue circles) were basically evenly distributed on both sides of the total effect size (blue rhombus). To completely eliminate publication bias requires 8 studies (red circles) with results between -0.5 and +0.5. Therefore, the funnel plot indicated that there was no serious publication bias in the study. Based on this, it can also be demonstrated that users' PU can have a positively effect on adoption.

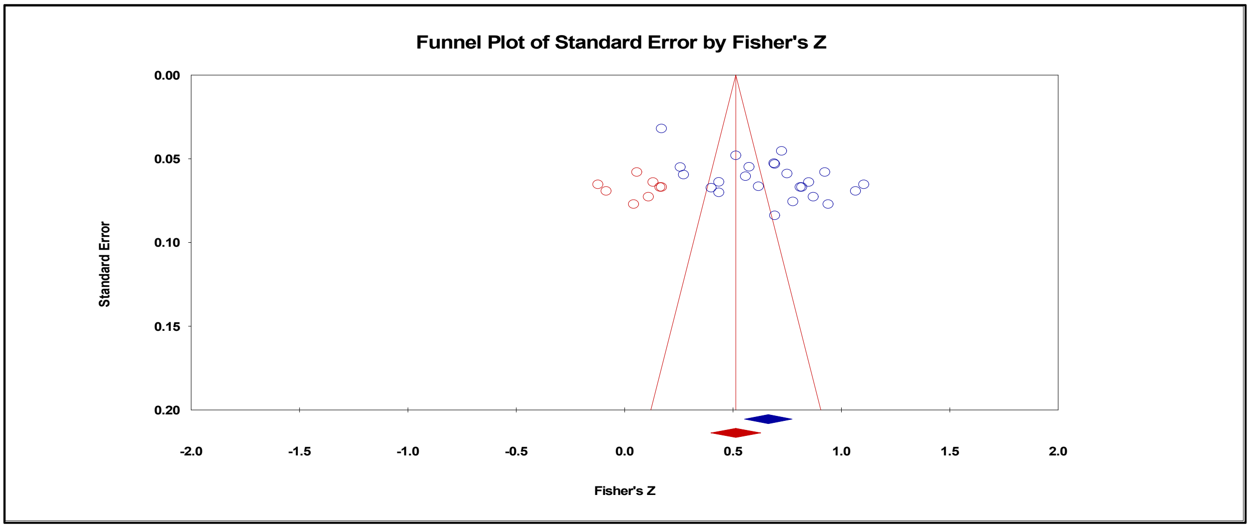


Figure 3. Funnel plot

The red line indicates the range of the published literature results distribution, with a median value of 0.5. The blue rhombus indicates where the results are presented as total effect size. The blue circles represent the distribution of results of published articles, and the red circles represent the results of articles that would need to be supplemented if published without any bias.

Further, the funnel plot is only a preliminary examination of publication bias from a subjective point of view, and more precise tests are needed using Rosenthals Classic (1979) Fail-safe N (Table 2) and Begg and Mazumdar (1994) rank correlation (Table 3). The results in Table 2 show that the failure safety factor between PU and adoption is 7108, which means an additional 7108 research papers are needed to deny the relationship. The failure safety factor ratio “Z-value” >1 (Z=52.366 in table 2), it shows that the sample is representative and there is no publication bias; The p-values of the Begg and Mazumdar rank correlation test on the outcome variables are all greater than 0.05 (P-value [1-tailed] =0.062; P-value [2-tailed] =0.124), indicating that there is no deviation between the study.

Table 2. Rosenthals Classic Fail-safe N check

| **Classic fail-safe N** | **value** |
|---|---|
| Z-value for observed studies | 52.366 |
| The P-value for observed studies | 0.000 |
| Alpha | 0.050 |
| Tails | 2.000 |
| Z for alpha | 1.960 |
| Number of observed studies | 24.000 |
| Number of missing studies that would bring p-value to>alpha | 7108.000 |

Table 3. Begg and Mazumdar rank correlation test

| **Begg and mazumdar rank correlation** | **value** |
|---|---|
| Kendall’s S statistic[P-Q] | 63.000 |
| Tau | 0.228 |
| Z-value for tau | 1.538 |
| P-value [1-tailed] | 0.062 |
| P-value [2-tailed] | 0.124 |

Last but not least, the trim and fill tests were used for re-analysis in the publication bias test (Table 4). The trim and fill tests were an iterative, nonparametric rank-based estimation method that has the advantage of providing more practical information and calculating the average effect size after correction for publication bias. As shown in table 4, after the trim and fill tests, the final effect size is equal to the initial observation value of 0.663, which indicates that the study is free of publication bias.

Table 4. Trim and fill test

| **Model** | **Random Effects** | | | **Q-Value** |
|---|---|---|---|---|
| Item | Point Estimate | Lower Limit | Upper Limit | |
| Adjusted values | 0.663 | 0.553 | 0.772 | 505.226 |

### 3.3. Heterogeneity test

The purpose of a heterogeneity test is to examine whether the measured effect sizes are heterogeneous between studies. This study conducted a heterogeneity test on the relationship between PU and adoption, and the results are shown in Table 5. It shows that the Q-test of the effect values between the studies is significant (P-value < 0.001), indicating that the effect values in the meta-analysis are heterogeneous. The I2 value (95.448%) is greater than 75%, indicating that there is high heterogeneity. A larger value represents a larger between-group variance of the studies, which can be attributed to actual differences between studies, rather than differences within studies. Compared with the Q statistic, I2 has two main advantages, one is that it is not sensitive to the number of studies included, and the other is that CI values can be calculated. Tau-squared can also be used to assess the amount of study heterogeneity in random-effects models. Heterogeneity exists when Tau-squared is not zero. The Tau-squared value in this study was 0.072, which proved the existence of heterogeneity.

Table 5. Judging Heterogeneity

| **Effect size and 95% interval** | | **Heterogeneity** | | **Tau-squared** | |
|---|---|---|---|---|---|
| Number Studies | 24 | Q-value | 505.226 | Tau Squared | 0.072 |
| Point estimate | 0.663 | df [Q] | 23 | Standard Error | 0.056 |
| Lower limit | 0.553 | P-value | 0.000 | Variance | 0.001 |
| Upper limit | 0.773 | I-squared | 95.448 | Tau | 0.268 |

### 3.4. Sensitivity analysis

The heterogeneity test suggested that the effect sizes were heterogeneous among the studies. According to the deviation of the funnel plot and effect size, a sensitive analysis was carried out on the heterogeneity effect size of the relationship between PU and adoption. After phasing out 16 studies the heterogeneity between PU and adoption was reduced to 94.1%, with effect size r=0.609, p<0.001 (Table 6).

Table 6. Statistical results after gradually removing 16 studies

| **Effect size and 95% interval** | | **Heterogeneity** | | **Tau-squared** | |
|---|---|---|---|---|---|
| Number Studies | 8 | Q-value | 407.258 | Tau Squared | 0.053 |
| Point estimate | 0.609 | df[Q] | 7 | Standard Error | 0.084 |
| Lower limit | 0.445 | P-value | 0 | Variance | 0.007 |
| Upper limit | 0.773 | I-squared | 94.1 | Tau | 0.23 |

The nineteen studies were gradually removed the heterogeneity was reduced to 84.241%, with effect size r=0.606, p<0.001 (Table 7). This finding implied that PU is highly related with adoption, regardless of the degree of heterogeneity.

Table 7. Statistical results after gradually removing 19 studies

| **Effect size and 95% interval** | | **Heterogeneity** | | **Tau-squared** | |
|---|---|---|---|---|---|
| Number Studies | 5 | Q-value | 250.383 | Tau Squared | 0.026 |
| Point estimate | 0.606 | df[Q] | 4 | Standard Error | 0.022 |
| Lower limit | 0.499 | P-value | 0 | Variance | 0 |
| Upper limit | 0.695 | I-squared | 84.241 | Tau | 0.162 |

### *3.5. Subgroup test: culture background and gender*

The heterogeneity test found that the effect sizes among the studies were heterogeneous, and there may be significant moderating variables. The subgroup test is one of the most commonly used methods to explore the source of heterogeneity. The variables in this study are all categorical variables, therefore the subgroup test is used to further investigate the source of heterogeneity and the moderating effect of factors. Because this study focuses on the moderating effects of cultural background (China, other countries) and gender ratio on the relationship between PU and adoption (Figure 4, Figure 5 and Table 8, Table 9). The study sets group "1" for the study region of China, and group 2 for other countries; the group with more males is "3", however, the group with more females is "4".

The results in Table 8 and Figure 4 show that cultural background significantly moderates the relationship between PU and adoption (other countries, r=0.670, p<0.001; China, r=0.658, p<0.001). The effect size of foreign users' PU and adoption is higher than that of the eastern cultural background.

Table 8. Cultural background modulates user adoption

| **First-level indicator** | **Secondary indicators** | **Group 1：China** | **Group 2：Other countries** |
|---|---|---|---|
| Effect size and 95% interval | Number Studies | 14 | 10 |
| | Point estimate | 0.658 | 0.670 |
| | Lower limit | 0.494 | 0.557 |
| | Upper limit | 0.821 | 0.783 |
| | Z-value | 7.887 | 11.645 |
| | P-value | 0.000 | 0.000 |

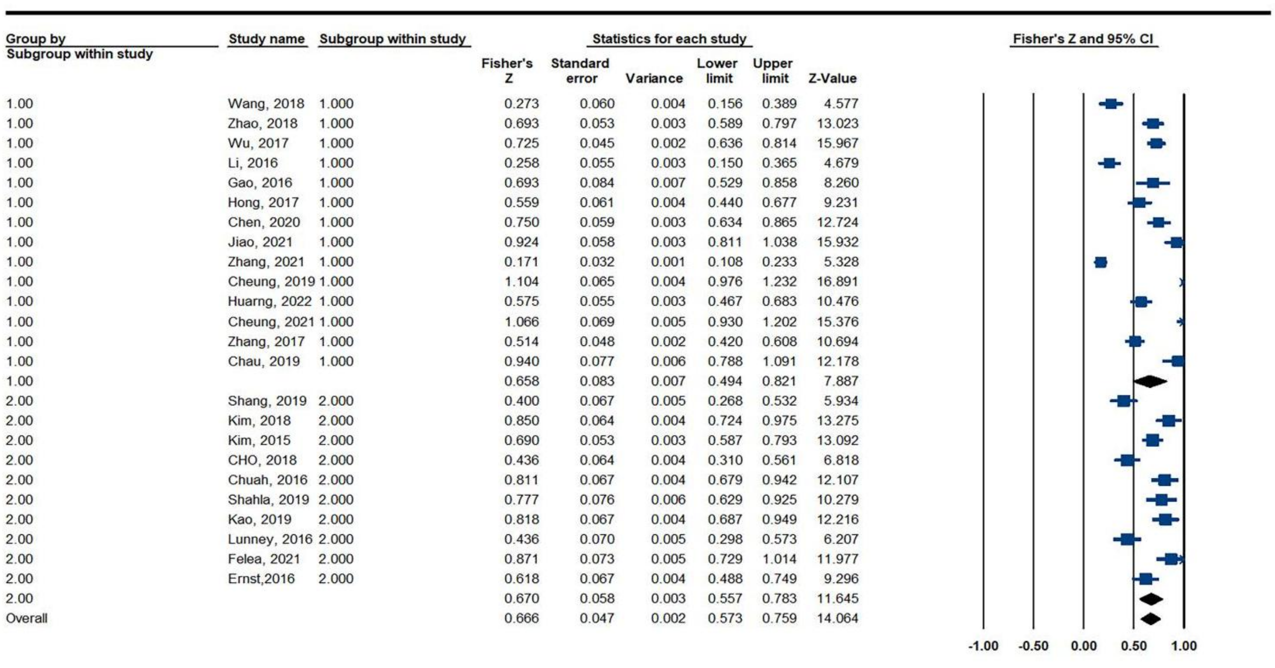


Figure 4. Forest diagram of cultural background regulating user adoption.

The results in Figure 5 and Table 9 show that the proportion of male and female respondents significantly moderates the relationship between PU and adoption (the proportion of females is higher, r=0.669, p<0.001; the proportion of males is more, r=0.658, p<0.001), suggesting that PU exert a greater impact on the adoption of female users.

| Group by Subgroup within study | Study name | Subgroup within study | Fisher's Z | Standard error | Variance | Lower limit | Upper limit | Z-Value |
|---|---|---|---|---|---|---|---|---|
| | | | Statistics for each study | | | | | |
| 3.00 | Wang, 2018 | 3.000 | 0.273 | 0.060 | 0.004 | 0.156 | 0.389 | 4.577 |
| 3.00 | Zhao, 2018 | 3.000 | 0.693 | 0.053 | 0.003 | 0.589 | 0.797 | 13.023 |
| 3.00 | Hong, 2017 | 3.000 | 0.559 | 0.061 | 0.004 | 0.440 | 0.677 | 9.231 |
| 3.00 | Zhang, 2021 | 3.000 | 0.171 | 0.032 | 0.001 | 0.108 | 0.233 | 5.328 |
| 3.00 | Cheung, 2019 | 3.000 | 1.104 | 0.065 | 0.004 | 0.976 | 1.232 | 16.891 |
| 3.00 | Huarng, 2022 | 3.000 | 0.575 | 0.055 | 0.003 | 0.467 | 0.683 | 10.476 |
| 3.00 | Cheung, 2021 | 3.000 | 1.066 | 0.069 | 0.005 | 0.930 | 1.202 | 15.376 |
| 3.00 | Chau, 2019 | 3.000 | 0.940 | 0.077 | 0.006 | 0.788 | 1.091 | 12.178 |
| 3.00 | Shang, 2019 | 3.000 | 0.400 | 0.067 | 0.005 | 0.268 | 0.532 | 5.934 |
| 3.00 | Kim, 2018 | 3.000 | 0.850 | 0.064 | 0.004 | 0.724 | 0.975 | 13.275 |
| 3.00 | Kim, 2015 | 3.000 | 0.690 | 0.053 | 0.003 | 0.587 | 0.793 | 13.092 |
| 3.00 | CHO, 2018 | 3.000 | 0.436 | 0.064 | 0.004 | 0.310 | 0.561 | 6.818 |
| 3.00 | Kao, 2019 | 3.000 | 0.818 | 0.067 | 0.004 | 0.687 | 0.949 | 12.216 |
| 3.00 | | | 0.658 | 0.089 | 0.008 | 0.483 | 0.832 | 7.404 |
| 4.00 | Wu, 2017 | 4.000 | 0.725 | 0.045 | 0.002 | 0.636 | 0.814 | 15.967 |
| 4.00 | Li, 2016 | 4.000 | 0.258 | 0.055 | 0.003 | 0.150 | 0.365 | 4.679 |
| 4.00 | Gao, 2016 | 4.000 | 0.693 | 0.084 | 0.007 | 0.529 | 0.858 | 8.260 |
| 4.00 | Chen, 2020 | 4.000 | 0.750 | 0.059 | 0.003 | 0.634 | 0.865 | 12.724 |
| 4.00 | Jiao, 2021 | 4.000 | 0.924 | 0.058 | 0.003 | 0.811 | 1.038 | 15.932 |
| 4.00 | Zhang, 2017 | 4.000 | 0.514 | 0.048 | 0.002 | 0.420 | 0.608 | 10.694 |
| 4.00 | Chuah, 2016 | 4.000 | 0.811 | 0.067 | 0.004 | 0.679 | 0.942 | 12.107 |
| 4.00 | Shahla, 2019 | 4.000 | 0.777 | 0.076 | 0.006 | 0.629 | 0.925 | 10.279 |
| 4.00 | Lunney, 2016 | 4.000 | 0.436 | 0.070 | 0.005 | 0.298 | 0.573 | 6.207 |
| 4.00 | Felea, 2021 | 4.000 | 0.871 | 0.073 | 0.005 | 0.729 | 1.014 | 11.977 |
| 4.00 | Ernst,2016 | 4.000 | 0.618 | 0.067 | 0.004 | 0.488 | 0.749 | 9.296 |
| 4.00 | | | 0.669 | 0.063 | 0.004 | 0.546 | 0.792 | 10.689 |
| Overall | | | 0.665 | 0.051 | 0.003 | 0.565 | 0.766 | 13.003 |

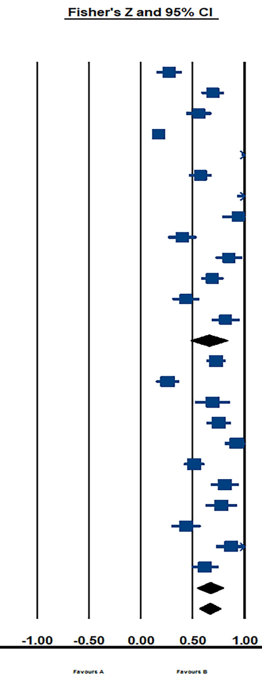


Figure 5. Forest plot of gender ratio regulating user adoption

Table 9. Gender ratio adjusts user adoption.

| First-level indicator | Secondary indicators | Group 3 | Group 4 |
|---|---|---|---|
| Effect size and 95% interval | Number Studies | 13 | 11 |
| | Point estimate | 0.658 | 0.669 |
| | Lower limit | 0.483 | 0.546 |
| | Upper limit | 0.832 | 0.792 |
| | Z-value | 7.404 | 10.689 |
| | P-value | 0.000 | 0.000 |

**3.6. Regression analysis: the COVID-19**

Based on the time showing a continuous variable, meta-regression analysis was used to examine whether the results of the pre-COVID-19 differed from the period of during COVID-19. The study set the pre-COVID-19 group to a "5" and its period to a "6". The results in Figure 6 and Table 10 show that the emergence of COVID-19 significantly improved the relationship between user PU and adoption (before COVID-19, r=0.580, p<0.001; during COVID-19, r = 0.762, p<0.005), it can be seen that the outbreak of the epidemic has promoted users' adoption of FWT to a certain extent.

| Group by COVID-19 | Study name | Fisher's Z | Standard error | Variance | Lower limit | Upper limit | Z-Value |
|---|---|---|---|---|---|---|---|
| 5.00 | Wang, 2018 | 0.273 | 0.060 | 0.004 | 0.156 | 0.389 | 4.577 |
| 5.00 | Zhao, 2018 | 0.693 | 0.053 | 0.003 | 0.589 | 0.797 | 13.023 |
| 5.00 | Wu, 2017 | 0.725 | 0.045 | 0.002 | 0.636 | 0.814 | 15.967 |
| 5.00 | Li, 2016 | 0.258 | 0.055 | 0.003 | 0.150 | 0.365 | 4.679 |
| 5.00 | Gao, 2016 | 0.693 | 0.084 | 0.007 | 0.529 | 0.858 | 8.260 |
| 5.00 | Hong, 2017 | 0.559 | 0.061 | 0.004 | 0.440 | 0.677 | 9.231 |
| 5.00 | Zhang, 2017 | 0.514 | 0.048 | 0.002 | 0.420 | 0.608 | 10.694 |
| 5.00 | Kim, 2018 | 0.850 | 0.064 | 0.004 | 0.724 | 0.975 | 13.275 |
| 5.00 | Kim, 2015 | 0.690 | 0.053 | 0.003 | 0.587 | 0.793 | 13.092 |
| 5.00 | CHO, 2018 | 0.436 | 0.064 | 0.004 | 0.310 | 0.561 | 6.818 |
| 5.00 | Chuah, 2016 | 0.811 | 0.067 | 0.004 | 0.679 | 0.942 | 12.107 |
| 5.00 | Lunney, 2016 | 0.436 | 0.070 | 0.005 | 0.298 | 0.573 | 6.207 |
| 5.00 | Ernst,2016 | 0.618 | 0.067 | 0.004 | 0.488 | 0.749 | 9.296 |
| 5.00 | | 0.580 | 0.052 | 0.003 | 0.478 | 0.683 | 11.071 |
| 6.00 | Chen, 2020 | 0.750 | 0.059 | 0.003 | 0.634 | 0.865 | 12.724 |
| 6.00 | Jiao, 2021 | 0.924 | 0.058 | 0.003 | 0.811 | 1.038 | 15.932 |
| 6.00 | Zhang, 2021 | 0.171 | 0.032 | 0.001 | 0.108 | 0.233 | 5.328 |
| 6.00 | Cheung, 2019 | 1.104 | 0.065 | 0.004 | 0.976 | 1.232 | 16.891 |
| 6.00 | Huarng, 2022 | 0.575 | 0.055 | 0.003 | 0.467 | 0.683 | 10.476 |
| 6.00 | Cheung, 2021 | 1.066 | 0.069 | 0.005 | 0.930 | 1.202 | 15.376 |
| 6.00 | Chau, 2019 | 0.940 | 0.077 | 0.006 | 0.788 | 1.091 | 12.178 |
| 6.00 | Shang, 2019 | 0.400 | 0.067 | 0.005 | 0.268 | 0.532 | 5.934 |
| 6.00 | Shahla, 2019 | 0.777 | 0.076 | 0.006 | 0.629 | 0.925 | 10.279 |
| 6.00 | Kao, 2019 | 0.818 | 0.067 | 0.004 | 0.687 | 0.949 | 12.216 |
| 6.00 | Felea, 2021 | 0.871 | 0.073 | 0.005 | 0.729 | 1.014 | 11.977 |
| 6.00 | | 0.762 | 0.110 | 0.012 | 0.545 | 0.978 | 6.908 |
| Overall | | 0.614 | 0.047 | 0.002 | 0.521 | 0.707 | 12.965 |

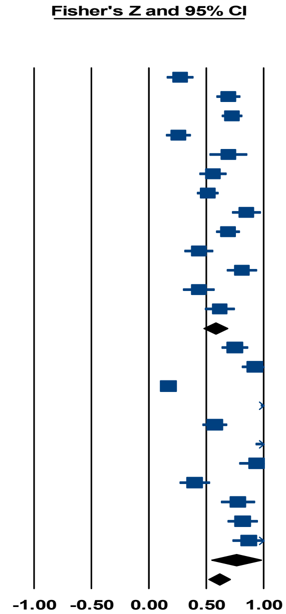


Figure 6. The forest diagram of the COVID-19 regulating the relationship

Table 10. The COVID-19 epidemic regulates the relationship

| First-level indicator | Secondary indicators | 5：pre-COVID-19 | 6 ： during COVID-19 |
|---|---|---|---|
| Effect size and 95% interval | Number Studies | 13 | 11 |
| | Point estimate | 0.580 | 0.762 |
| | Lower limit | 0.478 | 0.683 |
| | Upper limit | 0.545 | 0.978 |
| | Z-value | 11.071 | 6.908 |
| | P-value | 0.000 | 0.000 |

### 3.7. Model diagram

The study found that PU affects FWT user adoption and is influenced by cultural background, gender, and COVID-19. Therefore, a model graph was built in which the PU impact was adopted (Figure 7).

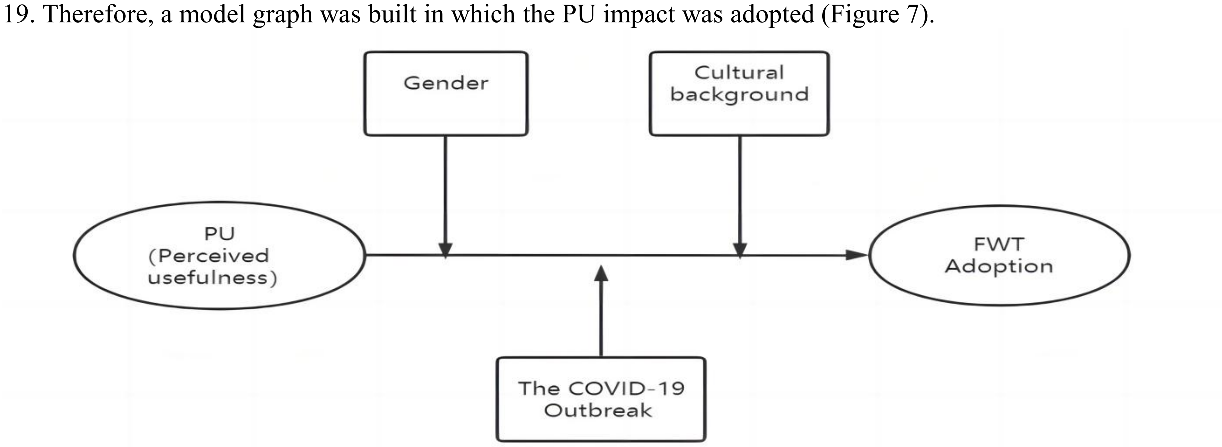


**Figure 7.** Model diagram of PU affecting FWT adoption

## 4. Discussion

### *4.1. PU affects FWT adoption*

The results show that PU is closely related to FWT adoption (r = 0.606, I2=84.241 in table 7) after removing highly heterogeneous literature, and that PU positively affects the adoption of FWT users. This conclusion is significantly greater than the results of previous studies (Chen, 2020; Wang, 2020). It is probably due to people may pay more attention to the PU of fitness wearables than other leisure wearables with advances in perception, localization, and biotechnology. The perceived fitness effect can be assisted by FWT for a period of time, it can be found whether it can promote personal fitness, exercise and other behaviors, whether the goals of "successful weight loss" and "reduction of body fat rate" can be achieved, etc. Data indicators can also be analyzed through the device to help you better understand your physical state during exercise, and enhance your positive cognition, positive emotions, and positive inner needs, making it easier for individuals to perceive the usefulness of the device, from satisfying expected performance.

For professional athletes, professional athletes can improve athletic performance by examining physiological data such as heart rate, running speed, and core temperature, as well as parameters such as joint angle or time, when applied to a sports environment (Strohrmann, 2012). The same is true for ordinary users, sports bracelets that are favored by people can not only help them track heart rate, analyze physical stress and recovery status, improve users' physical fitness without overtraining, but also provide physical fitness data for ordinary users. With the changing times and technological advancement, FWT users have not neglected the PU of the device while enjoying the convenience, innovation, and personalization of the device. This shows that FWT has become a fast-growing and widely adopted technology that is changing people's lifestyles and improving the decision-making and behavior of fitness people.

Therefore, developers and manufacturers of FWT should leverage digital intelligence to continuously improve the usefulness of the device. Market segmentation for ordinary people and athletes, improving information exchange between users through the Internet of Things, enhancing personal PU experience, and personal adoption of fitness wearable technology, and user stickiness and trust. In the future, we can continue to enhance the functionality of the device to facilitate user stimulation and cultivation of fitness outcomes and PU perception, further enhancing individuals' willingness to take actions.

### 4.2. Moderating effect of PU on user adoption

#### 4.2.1 Cultural background

Cultural background significantly moderated the relationship between PU and adoption rate (other countries, r=0.670, p<0.001; China, r=0.658, p<0.001). The coefficient value of users in other countries is higher compared with China, indicating that the influence of personal PU on adoption in other countries' cultural background is higher than that of Chinese cultural background. Likewise, previous studies have also shown that PU has different effects on user adoption in different cultural contexts, supporting our results (Kim, T., & Chiu, W. (2019).

The results of this study are contrary to some previous research views, such as Abbey Lunney et al. (2016) view: "Users in other countries perceive PU to have a lower impact value". After excluding the age of the respondents, survey methods and other factors, the main reasons are summarized: (1) A comparative study of the literature with different opinions in 2016 found that at the beginning of the 21st century, the overall living standard of China's economy was lower than that of developed countries, and its scientific and technological strength was lower than that of developed countries. It is also weaker than Europe, America and South Korea in the same period. Therefore, under the background of the lack of direction and pertinence of high-tech products at that time, Chinese users paid more attention to the functionality and practicality of fitness wearable technology. However, with the rise of China's comprehensive strengths in economy, culture, and technology, as well as the blessing of digital intelligent technologies such as big data, cloud computing, and the Internet of Things, Chinese users' pursuit of FWT has gradually shifted to differentiation, intelligence, and personalization. (2) Since most of the respondents are Internet users, the overall age level is relatively low, and they enjoy the technological dividends brought by the country's prosperity. In contrast, the higher level of PU experienced by Chinese users is replaced by other factors, and the relationship between PU and adoption rate is naturally lower than that of foreign perceptions. (3) Eastern and Western cultures have different understandings of PU. Western cultural backgrounds, especially European and American countries, pay more attention to the gratitude for the creation of the world by God, thus extending the gratitude to the world created by God and even the objects in daily life (Park, 2009). (4) According to existing research, the female's obesity rate and overweight rate of European and American people are relatively high (Qiu, 2021). When female users use FWT, the purpose is clear to achieve the effect of exercise or fitness. After using it for a period of time, their perceived fitness effect of FWT may be more obvious than that of the Chinese.

Based on the foregoing study, we have cause to provide recommendations to FWT manufacturers: while marketing products in other countries such as Europe and the United States and so on, they can emphasize FWT's perceived utility. In order to capture public attention while selling in the Chinese market, it is vital to make full use of advanced technology in addition to paying attention to perceived usefulness.

**4.2.2 Gender analysis**

The gender ratio has a moderating effect on user adoption, and the effect is significant (more girls, r=0.669, p<0.001; more boys, r=0.658, p<0.001). The effect size of female behavior is relatively higher than the coefficient value of male perception. Female believe that PU has a greater impact on user adoption. The main reasons are: (1) Due to the inherent gender prejudice in traditional culture, it is believed that women should educate their husbands and children, handle housework, and label women as "thrifty and pragmatic". The truth of pragmatism is the combination of idea and reality. It believes that the value of human cognition lies in its results and whether it can satisfy human's "useful" requirements. Pragmatism strongly advocates a "philosophy of practice", which advocates that human knowledge and practice, needs and interests, as well as body and society, should be integrated. Therefore, when adopting fitness wearable technology, it is believed that PU has a greater impact on adoption, which is in line with subjective norms. Male are given pronouns such as "adventure", "novelty" and "stimulation". When choosing equipment, they may pay more attention to other factors such as differentiation and personalization of FWT. (2) In daily life, women pay more attention to body management and are more "beautiful" than men. When adopting fitness wearable technology, they pay more attention to the perceived fitness results of the device, whether they can achieve the weight loss, slimming, shaping and other purposes, and Health beliefs that affect women's PU (Zhang, 2017). Therefore, manufacturers of FWT should show the product's perceived usefulness to potential female consumers, as well as the other benefits of FWT to male users.

**4.2.3 Impact of COVID-19**

The occurrence of the COVID-19 epidemic has a significant moderating effect on user adoption (for example, before the epidemic, r=0.580, p<0.001; during the epidemic, r=0.762, p<0.005). At the end of 2019 A.D., with the outbreak of the epidemic, various countries adopted home isolation policies to varying degrees, and people in all countries had to exercise at home to maintain their health. Before the outbreak of COVID-19, people were more inclined to go out indoors, embrace the natural environment, and pay more attention to various outdoor sports. However, after the outbreak of COVID-19 in 2019, people began to pay attention to whether exercising at home can improve physical condition, PU of fitness wearable technology, etc., and focus on fitness wearables they own. Technically, self-monitoring is expected to be carried out through such devices, and at the same time, the emotion of anticipation of health will be transferred to fitness wearable technology, so as to improve the favorability and adoption of such devices. Manufacturers of FWT should seize the opportunity of the pandemic to advertise their goods to the general public. Governments throughout the world should support FWT to enable individuals who are isolated at home exercise more effectively, monitor their physical status in real time, and stay healthy.

*4.3. Research significance, limitations, and prospects*

Based on a meta-analysis approach, this paper quantitatively analyzes and examines 24 literatures on FWT user adoption. After collating and recording the literature, descriptive statistics and reliability analysis were performed on the variables, and correlation analysis was performed on the research variables to obtain the research summary on PU and adoption rate provided by FWT users, which has certain implications for scholars and wearable device providers, and broadens the research field of meta-analytical methods. Combined with the research results, it is found that FWT providers can improve the attractiveness of the product itself from the aspect of product PU, and attract more users to use fitness wearable technology.

However, this study only considers user gender, cultural differences between countries, and differences before and after the epidemic, and does not consider technological gaps between regions. Future research can build a block chain technology framework, and introduce related mechanisms to provide fitness wearable technologies and services for free, and develop multiple functions of the device to improve PU, which may increase users' willingness to adapt and adopt behaviors.

**5. Conclusions**

The present study was designed to determine the link to comprehend the detailed numerical values between PU and FWT adoption since January 1, 2015 to March 1, 2022 A.D. The relevance (0.663) of PU and FWT adoption is clearly supported in this meta-analysis by the random-effects model. One of the more significant findings to emerge from this study is that gender (0.669), cultural background (0.670), and COVID-19 (0.762) can deepen this relationship to varying degrees, as verified by these results are all greater than the value (0.663) before using the moderator variables. More precisely, subgroup test shows that female tend to have greater impact on FWT adoption than men, users in other countries pay more attention to PU than Chinese users. The findings of this investigation not only complement those of earlier studies, but also appears to be the first study to compare the relationship between PU and FWT adoption pre-COVID-19 and during COVID-19. With regression analysis the coefficient of PU's impact on adoption increases significantly after the COVID-19 outbreak, indicating that people need FWT-assisted exercise to understand and maintain their own physical fitness. The major limitation of this study is that it did not take into account technological changes. In spite of its limitations, the study certainly adds to our understanding of the relevance of PU and FWT adoption. Furthermore, the findings of this study have a number of important implications for future practice. For instance, Government departments need to continue to make efforts to make FWT more easily applied to national fitness work under the epidemic. Simultaneously, relevant researchers must continue to develop the PU of FWT and segment the sales market in order to raise the public's adoption.

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