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# The effectiveness of structured exercise in the south Asian population with type 2 diabetes: a systematic review.

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**Background:** The impact of exercise interventions on south Asians with type 2 diabetes (T2DM), who have a higher T2DM incidence rate compared to other ethnic groups, is inconclusive. This study aimed to systematically review the effect of exercise interventions in south Asians with T2DM.

**Method:** Five electronic databases were searched up to April 2017 for controlled trials investigating the impact of exercise interventions on south Asian adults with T2DM. The Pedro scale was used to assess the quality of the included studies.

**Results:** Eighteen trials examining the effect of aerobic, resistance, balance or combined exercise programs met the eligibility criteria. All types of exercise were associated with improvements in glycemic control, blood pressure, waist circumference, blood lipids, muscle strength, functional mobility, quality of life or

neuropathy progression. The majority of included studies were of poor methodological quality. Few studies compared different types or dose of exercise.

**Conclusion:** This review supports the benefits of exercise for south Asians with T2DM, although it was not possible to identify the most effective exercise prescription. Further studies of good methodological quality are required to determine the most effective dosage and type of exercise to manage T2DM in this population.

**Keywords:** Type 2 diabetes; Exercise; ethnicity; South Asian; management

## 1. Background

Type 2 diabetes (T2DM) is one of the most common chronic diseases affecting more than 415 million people worldwide (1). Although T2DM affects people from all ethnic backgrounds, south Asians (people who have originated from Pakistan, India, Sri Lanka, Nepal, or Bangladesh) are considered to be one of the ethnic groups that largely contribute to this high prevalence rate (2). South Asians are up to six times more likely to have T2DM than white European people, with the onset of T2DM occurring 5-10 years earlier in this population (3–5).

Exercise is considered a core element in T2DM management and has been found to improve a number of factors strongly linked to T2DM and its complications, such as glycemic control, high blood pressure, and abnormal blood lipid profiles, muscle weakness, neuropathy, functional decline, and poor quality of life (6–8). However, the available evidence regarding the effects of exercise emerged from studies mainly including people of white European background (9). Studies investigating the impact of exercise in people of

different backgrounds indicated variation in exercise responses among ethnic groups due to physiological, psychological, genetic, social and cultural factors (10,11). Therefore, the generalizability of the available evidence is limited.

To date, no systematic review has specifically explored the impact of exercise on south Asians with DM2. Recently, Bhurji et al. (12) reviewed the effects of different management strategies targeting south Asians with T2DM and found limited improvements that failed to reach level of statistically significant in glycemic control, while interventions comprising of exercise or yoga were most successful. However, of the 23 studies included in this review only 4 consisted of an exercise only intervention, of which one study did not have a control group. Therefore, the aim of this systematic review was specifically to review controlled trials investigating the effect of exercise interventions in south Asian adults with T2DM.

## **2. Methods**

### ***2.1. Data sources and search strategy***

Electronic searches were conducted up to April 2017 of the following databases: Medline, Embase, Cochrane Library, CINAHL, and Physiotherapy Evidence Database (PEDro). The keywords were divided into three categories, namely condition of interest (i.e. T2DM), ethnicity (i.e. south Asian), and intervention (i.e. exercise). Keywords and medical subheadings related to every category were combined together with the Boolean operator “OR”. Then, the Boolean operator “AND” was used to combine categories. Search strategies were tailored to each database (Appendix 1). Reference lists of included articles and systematic reviews in the field were also searched manually for relevant studies.

To be included in this review, articles had to be of either randomized controlled trials (RCTs) or non-randomized controlled clinical trials (CCTs), written in English, included solely south Asian adults with T2DM or where there was a mixed sample of Diabetes or ethnicity distinct results for south Asians with T2DM were presented, evaluated an exercise program and reported at least one T2DM health-related outcome. For the purpose of this review, exercise was defined as a structured predetermined physical activity program lasting four weeks or more. Articles were excluded if programs compromised of dance, yoga or only provided advice or a recommendation to increase physical activity. Reviews, cross-sectional, case-control, case series studies and abstracts only were also excluded.

## ***2.2. Study selection***

All references retrieved from the electronic and manual searches were exported and added to a web-based systematic review tool ([www.covidence.org](http://www.covidence.org)) (13). To determine whether the papers met the inclusion/exclusion criteria, two independent researchers [LP and HA] initially scanned the titles and abstracts. Articles then were read in full. Inconsistencies in study selection were resolved by discussion between the two researchers.

## ***2.3. Quality appraisal and data extraction***

Three reviewers [HA, EC, LP] were involved in assessing the methodological quality of the included studies using the PEDro scale (14). The PEDro scale is a valid and reliable tool which scores papers based on 10 criteria (14). Each article was reviewed and scored by two assessors independently. Discrepancies were resolved by discussion including the third reviewer if required. Trials which scored 6 or higher in the PEDro scale were considered to be of good quality, while those which scored less than 6 were considered to be of poor quality

(15). Data were extracted from each study by one reviewer (HA). When two or more articles were from the same study but reported either different outcome measures or results from different assessment times, they were combined and considered as a single study. Authors of such studies were contacted for clarification.

### ***3. Results***

#### ***3.1. Description of the included studies***

The search identified 2,292 potentially related publications, of which 2274 articles were screened after duplicates were removed. The full text of 49 articles was screened for eligibility, from which 23 articles were included for review (16–38). These 23 articles reported findings from 18 original trials (Figure 1; Table 1).

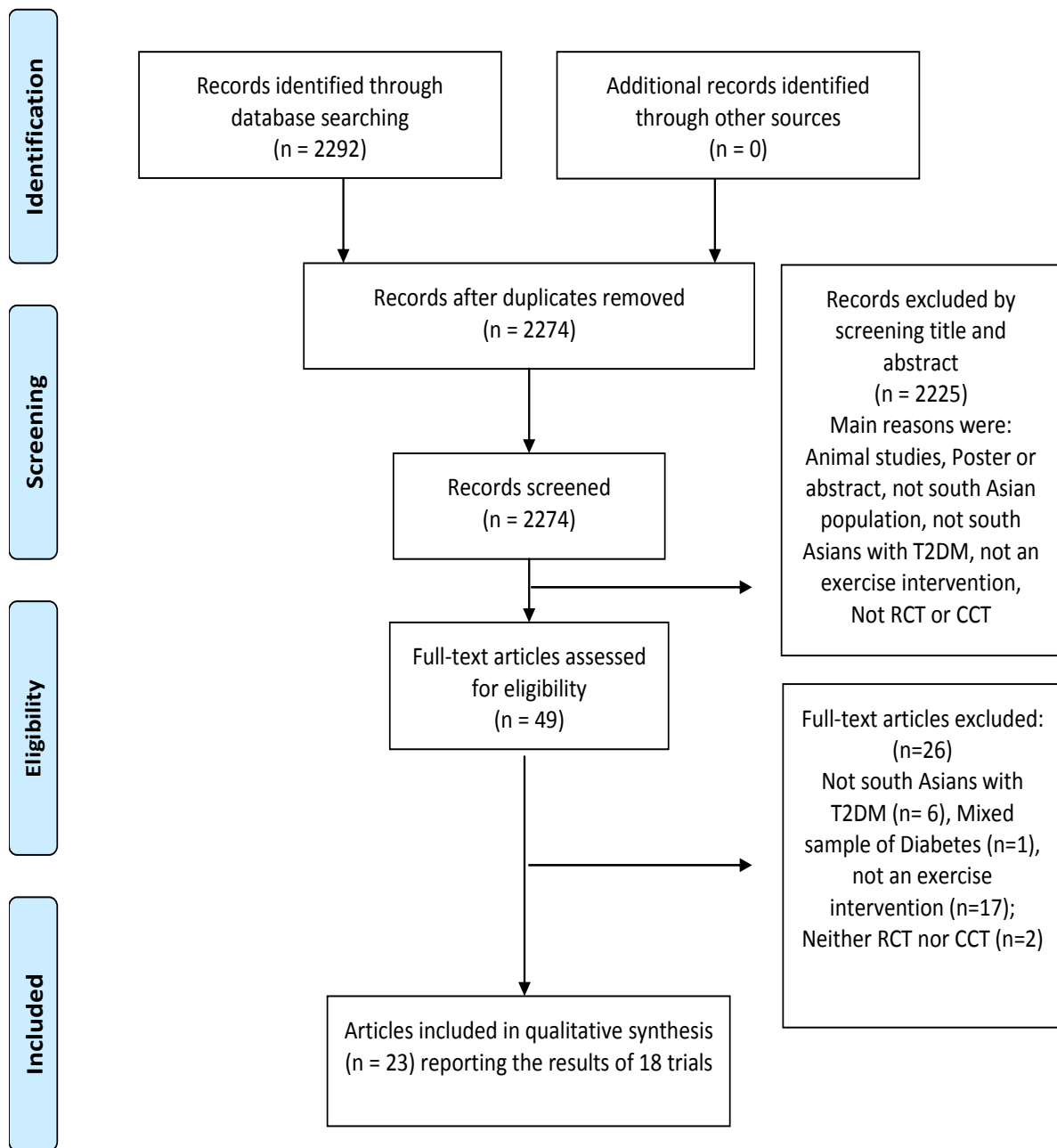


Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses, flowchart of screening and inclusion process of included trials.

Table 1 Near Here

Of the 18 trials included, 16 were RCTs and two were CCTs (35,36). The majority of these trials (n=15) were of poor methodological quality scoring less than 6/10 on the PEDro scale (Table 2). Only one trial, published in two articles, stated that the assessor was blinded (33,34) and the ‘concealed allocation’ criterion was satisfied in only one trial (16). Six trials did not provide between-group analysis (18,20,21,25–28,38). Only three trials, published in 4 articles, conducted sample size calculations (22,33,34,37).

[Table 2 Near Here]

### ***3.2. Participant characteristics***

The 18 trials included 1063 participants, of whom 959 (90%) were Indian. The time since diagnosis of T2DM was at least six months in seven trials (16,22–24,30–32). The remaining studies did not report T2DM duration. All studies excluded people with contraindications to exercise such as uncontrolled hypertension. Five studies included only participants with complications strongly linked to T2DM, such as neuropathy (34,38), hypertension (27), obesity (18,35) and restriction in physical performance due to obesity and age-related conditions (35).

### ***3.3. Characteristics of exercise program***

Of the included 18 trials, 15 compared exercise to control situations. Two trials compared the efficacy of two different exercise programs (17,31) and one trial with three intervention arms examined the efficacy of two exercise programs compared to usual care (23). The programs



involved aerobic exercise (n=10)(17,23,29–31,33,35–37), resistance exercise (n=7) (19–23,26,27), combined aerobic and resistance (n=3) (16–18), and balance exercise training (n=1) (38).

### *3.3.1. Aerobic exercise*

Aerobic exercise programs were prescribed in ten trials (17,23,29–31,33–37), of which eight programs were fully supervised, while two studies prescribed either partially supervised (29) or unsupervised programs (35). The length of aerobic programs varied ranging from 4 to 52 weeks (29,30). The modes of aerobic exercise were walking with pedometers (n=1) (31), walking with heart-rate monitors (n=1) (32), walking on a treadmill (n=3) (34,36,37), walking alone (n=3) (23,29,35), stationary cycling (n=1)(30), or a combination of different modes of aerobic exercise (n=1) (17).

Nine trials reported session duration ranging from 30 to 60 minutes and a frequency of three to five days per week (17,23,29–31,33,34,36,37). Similarly, the intensity was defined as moderate in five exercise trials according to heart-rate reserve (32,33) or the Borg Rating of Perceived Exertion Scale (29,31,36), while intensity was not reported in four trials (17,23,30,37). Only one study included people with mobility limitations, which reported daily, light intensity exercise of five minutes of walking every hour for most waking hours (35).

### *3.3.2. Resistance exercise*

Seven supervised, progressive resistance programs were prescribed in six trials (19–24,26,27). The length of these programs ranged from 4 to 16 weeks. The volume of resistance exercise was reported in terms of number of repetitions and sets performed. In four trials the

volume was consistent with 3 sets of 10 repetitions (20–23). Only one study specified a rest interval between sets of two minutes (22). The remaining two studies reported neither volume nor time (19,27):

All studies reported targeting the major muscle groups of the body and incorporated exercises such as hamstring curls, sit-ups and wall-squats. These exercises were most frequently performed using a Swiss-ball (n=4) (19–21,28), two programs used weight machines (22,23), and one program used resistance bands (19). The majority of programs were performed three times per week (n=5) (20,24,26–28). One program was performed two times per week (23). Another program was undertaken two to three times a week based on participants' preference (22).

### *3.3.3. Combined exercise*

Supervised combined exercise programs were described in three trials (16–18). The length of these programs were 8 (16), 10 (17), and 24 weeks (18). Only two studies reported duration, and in those two studies sessions lasted 60 minutes (16,17). Two studies included aerobic and resistance exercise in the same session two or three times per week respectively (16,17), while one study prescribed aerobic and resistance training in different sessions (three days aerobic and two days resistance per week) (18).

Two of the three combined programs involved traditional aerobic and resistance exercise (17,18), whereas one program employed culturally adapted aerobic exercise (Bollywood dance) plus traditional resistance exercise (16). The intensity of the aerobic and resistance components of the combined exercise was not reported in any of the studies.

### *3.3.4. Balance exercise training*

Only one trial prescribed supervised balance exercise (38). The program consisted of multisensory exercises including walking forwards, backwards, and sideways with eyes both open and closed, on different ground surfaces for various distances at different speeds. This program was undertaken for 30 minutes, three times per week for six weeks.

### **3.4. Effects of different exercise programs**

All exercise interventions described, regardless of the type of exercise, found positive effects on at least one outcome (Table 3). Six trials provided information related to adverse events, three of which stated there were no exercise-related injuries or serious complications (21,23,36). Two trials described “a few” episodes of mild hypoglycemia and one trial reported muscle soreness as a result of resistance exercise, however none resulted in non-compliance with exercise or required hospital admission (20,22,26). None of the included trials provided follow-up assessment beyond the end of the intervention period.

[Table 3 Near Here]

#### *3.4.1. Effects on glycemic control*

Thirteen trials examined the impact of exercise interventions on glycemic control in south Asians with T2DM (16–22,24,27,30,32,33,35). Glycated hemoglobin (HbA1c), was the main glycemic control measure in 10 trials (16,18,20–22,24,27,30,32,35). Six trials, involving seven exercise programs demonstrated that eight weeks or more of aerobic (n=4) (24,30,32,35), resistance (n=2) (22,24), or combined (n=1) (16) exercise programs were associated with a significant improvement in HbA1c compared to a control group (16,22,23,30,32,35). The remaining trials did not provide between-group analysis, yet these

trials reported a significant reduction in HbA1c following resistance exercise compared to baseline values, while the control groups showed an increase or no change in HbA1c (18,20,21,27).

Other glycemic control measures such as fasting blood glucose (FBG) levels and postprandial glucose levels (PPBS) were assessed in eight studies (17,19,20,23,29,32,34,36). Six studies found a significant improvement in these measures following aerobic (23,29,32,36), resistance (23) or combined exercise (17) compared to usual care or another exercise intervention (combined more so than aerobic) (17). Only two studies did not find significant differences in FBG between groups (19,34). Bashyal et al. (19) compared two resistance exercise programs and reported significant improvements in both groups compared to baseline. However, this study did not include an inactive control group for comparison. Dixit et al. (34) examined the impact of eight weeks of aerobic exercise compared to usual care. The exercise group showed improvement although the results were not statistically significant.

#### *3.4.2. Effects on blood pressure*

Five trials investigated the impact of exercise interventions on blood pressure (22,24,27,30,32). Four trials, involving five exercise programs, demonstrated that aerobic (n=3) or resistance (n=2) exercise significantly improved both systolic and diastolic blood pressure compared to baseline or a control group (22,24,27,30,32). Only one study, consisting of 8 weeks of resistance exercise, did not find a statistically significant improvement in blood pressure<sup>27</sup>. This study was of shorter duration compared to other resistance programs (<12 weeks) (24,27).

### *3.4.3. Effects on blood lipids*

Three studies examined the impact of exercise on blood lipid profiles (22,23,37). All these studies found positive results following either aerobic or resistance exercise (22,23,37). Hameed, et al. (22) found that eight weeks of resistance exercise was associated with a significant increase in high-density lipoprotein cholesterol compared to usual care (22). Arora, et al. (23) found that 16 weeks of either aerobic or resistance exercise programs significantly reduced total cholesterol compared to usual care. Neither noted a change in triglycerides or low-density lipoprotein levels. Despite this, Shakil et al. (37) conducted a trial of longer duration (25 weeks) finding significant improvement in both high and low-density lipoprotein cholesterol compared with usual care (37). This study did not measure triglycerides.

### *3.4.4. Effects on anthropometrics*

Ten trials reported body mass index (BMI), weight, waist circumference or waist-hip ratio (16,18,20–23,27,32,33,35). Waist circumference improved significantly following resistance exercise as compared to a control in one trial (22). The remaining trials did not report improvements (16,22,23,32,33,35) or the results were limited due to the lack of between group analysis (18,20,21,26).

### *3.4.5. Effects on muscle strength*

Two studies examined the effect of exercise on muscle strength using either one repetition maximum strength tests (22), or isotonic/isometric dynamometer software (23). These trials demonstrated that either aerobic or resistance exercise improved muscle strength in south Asians with T2DM (22,23). Hameed et al. (22) found 12 weeks of progressive resistance

exercise led to statistically significant improvements in lower and upper body musculature strength compared to a control group (22), and Arora et al. (23) found 16 weeks of either aerobic or progressive resistance exercise improved strength of the muscles of the lower part of the body compared to usual care.

#### *3.4.6. Effects on balance/functional mobility*

Three trials reported positive results on balance and functional ability following aerobic (24,35), resistance (24) or balance exercise (38). Two trials specifically included people with physical limitations (35,38). Majeed, et al. (38), which included south Asians with T2DM and peripheral neuropathy, reported significant improvements in functional mobility, measured by the 'timed up and go' test, following a 6 week balance exercise program. Seshadri, et al. (35), which included elderly, obese south Asians with T2DM who were unable to walk for long distances, reported significant improvements in the six-minute walk test after 24 weeks of light-intensity aerobic exercise. However, this improvement was not significant compared to usual care. The lack of between group improvements may have been due to the low sample size (n=9 per group). The third trial, Arora et al (23). demonstrated 16 weeks of either aerobic exercise or resistance exercise induced significant improvements in balance compared to a control group, measured using the Berg Balance Scale (24).

#### *3.4.7. Effects on quality of life and well-being*

Nine trials assessed quality of life and/or well-being (17,19,23,26,29,31–33). Six trials found aerobic (n=4), resistance (n=1) or combined exercise (n=1) significantly improved quality of life compared to control (17,19,23,26,29,31–33). Three trials did not report significant between group differences, yet reported significant improvements compared to baseline

(19,28,35). The lack of between group differences, in two trials, may have resulted from the inclusion of an active control group (19) or under powered sample size (35). The third trial did not perform between-group analysis (28). However, there was heterogeneity in terms of outcome measures used. These outcomes included the 36-item short-form Survey, Fourteen items measuring quality of life (14-QOL), Audit of Diabetes Dependent Quality of Life (ADDQoL19), Diabetes specific quality of life questionnaire, Neuropathy quality of life questionnaire, well-being questionnaire, 22-items self administered well being questionnaire of Bradley and Lewis.

#### *3.4.8. Effects on physiological measures related to neuropathy*

Two trials reported measures related to neuropathy and showed positive results following aerobic exercise (30,34). Sridhar et al. (30) examined the impact of 52 weeks of aerobic exercise on cardiac autonomic function measured by heart-rate variability (HRV) with a deep breath (30). This study reported a significant improvement in HRV for the exercise group compared to usual care. Dixit et al. (34) compared the effectiveness of eight weeks of moderate-intensity aerobic exercise with usual care (34). The intervention group demonstrated a statistically significant improvement in the Michigan Diabetic Neuropathy Score (MDNS) and nerve conduction velocity. However, the study did not show improvements in other nerve conduction parameters for peroneal and sural nerve.

#### *3.5. Optimal exercise strategy*

Three trials, published over four articles, compared the effects of different exercise interventions (17,19,23,24). Arora et al. (23) indicated that both aerobic and resistance exercises are effective in improving glycaemic control, blood pressure, and increasing muscle

strength yet, resistance exercise was found to be more beneficial. The results of this trial were limited by small sample size (n=10 in each group). Paul & Mary<sup>21</sup> found combined exercise was superior to aerobic exercise alone in terms of improving quality of life and decreasing fasting blood glucose levels (17). Bashyal, et al. (19) compared the effects of two resistance exercise programs; one using a Swiss ball and another using resistance bands. There were no between-group differences in quality of life or fasting blood glucose (19). None of these trials compared the effect of other exercise variables (intensity, frequency, duration). It is therefore difficult to determine the optimal exercise program for south Asians with T2DM.

#### **4. Discussion**

This is the first systematic review to specifically consider exercise interventions targeting south Asians with T2DM. Overall, in line with systematic reviews involving mainly white European participants with T2DM (6–8), the evidence presented within this review was positive regarding the efficacy of exercise in south Asians with T2DM. Exercise was also well tolerated by participants (20–23,26,36).

Aerobic exercise alone or resistance exercise alone were the most common types of exercise investigated in south Asians with T2DM and were associated with improvements in glycaemic control, blood pressure, blood lipid profile, muscle strength, functional mobility, and quality of life (17,23,24,29–31). There was little evidence to support or refute the efficacy of balance or combined exercises on the majority of these outcomes. Balance exercise was investigated in only one trial finding improvements in functional mobility (38). Combined exercise was explored in three trials reporting positive results in terms of improving glycemic control and quality of life (16–18). As such, more studies are required to



investigate the impact of such types of exercise in a wide range of outcomes in south Asians with T2DM.

Exercise type and dosage variables (intensity, frequency and duration) have previously been found to be associated with the overall effects of exercise programs in people with T2DM (39,40). In the current review, however, there was a dearth of trials comparing different types, modes, or doses (frequency, duration, and intensity) of exercise on diabetes related outcomes, making it difficult to identify the most effective prescription of exercise to improve T2DM management among south Asians. Systematic reviews involving mainly white European participants with T2DM found that aerobic exercise was superior to resistance exercise programs in terms of improving glycemic control and blood lipid profiles, whereas combined interventions were more beneficial than either aerobic or resistance exercise alone (6). Yet, the results of the current review indicate that the generalizability and transferability of these findings to south Asians with T2DM may be limited.

Only one trial examined the impact of two different types of exercise on both glycemic control and blood lipid profile (23). Arora et al. (23) found that resistance exercise was more beneficial than aerobic exercise. This finding is consistent with a RCT comparing the impact of aerobic and resistance exercise on people of white European backgrounds and African Americans with T2DM, another ethnic group disproportionately affected by T2DM (41). This study showed that resistance exercise was more beneficial for African Americans in terms of glucose metabolism. However, more studies of good methodological rigor are required to compare the impact of different types of exercises on south Asians with T2DM.

Although optimal dosage variables cannot be determined based on available literature, the majority of studies included in this review adhered to the widely recommended dosage of aerobic and resistance exercises for people with T2DM (42,43). It is recommended that

people with T2DM undertake 150 minutes of moderate aerobic exercise weekly, in bouts of at least 10 minutes (43). Progressive resistance exercise programs should involve the main muscles and be undertaken 2-3 times weekly (42,43).

The current review also indicates that obese south Asians with T2DM with physical limitations may even benefit from lower doses of aerobic exercise e.g. light intensity walking of 5 minutes every hour. Since south Asians have been identified as less active than white Europeans and as having greater complications associated with T2DM (44), it is possible that exercise with short bouts at a light intensity of aerobic exercise may be effective. However, this evidence emerged from only one study of a small sample size and poor methodological quality.

None of the studies included within this review reported significant improvement in BMI or weight. The impact of exercise alone on weight and BMI remains controversial(45,46). To reduce weight, interventions incorporating diet and exercise produce better results than those comprising of exercise alone (47).

The evidence, however, should be interpreted with caution due to the methodological limitations. In addition, changes to diet and medication may confound the effect of exercise on some outcomes such as glycemic control, blood pressure, and blood cholesterol (48), yet this was not reported in any of the included trials. Furthermore, the findings regarding the impact of exercise on blood lipids profiles, muscle strength, neuropathy, and functional mobility were based on a limited number of trials (22,24,34). There is a paucity of studies reporting a wide range of T2DM related outcomes. The majority of studies were conducted in India with Indian participants therefore, the findings may not be generalized to those of other south Asian backgrounds or those living in western countries.

#### ***4.1. Limitations***

The ability to draw a strong conclusion in this review was hampered by the quality of the included trials. The majority of the included trials were of poor methodological quality. In addition, this review did not include unpublished studies. It was further limited by the broad spectrum of interventions and outcomes which limited recommendations for exercise prescription. In addition, two authors were contacted for clarification but no reply was received.

#### **5. Conclusion**

This systematic review supports the benefits of exercise for south Asians with T2DM. All types of exercise were associated with improvement in at least one factor related to T2DM management in south Asians which included glycemic control, blood pressure, waist circumference, blood lipids, muscle strength, neuropathy progression, functional mobility, and quality of life. Although, it was difficult to determine the best exercise prescription, the results indicate that south Asians with T2DM may benefit from lower doses of exercise than the recommended level for people with T2DM. Future studies, of good methodological quality, are required to further investigate the impact of exercise type, dosage and long-term effect on T2DM management in south Asians.

Conflict of interest

All authors have no conflicts of interest.

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None

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Table 1 Evidence table.

| Authors, Design, Country                   | Participants   | Exercise intervention  | Comparison /control                  | Time points (wk) | Outcomes   | Change in outcomes   | Adverse events |
|--|--|--|--------------------------------------|------------------|--|--|----------------|
| Rekha et al. <sup>29</sup><br>CRT, India   | 53 Indians, 35-55 y/o with T2DM For [duration NR]. Comorbidity: No | 4 wk partially-supervised Home based AE: walking for 45 mins, x5/wk, Intensity: PRE at 12-14                               | Usual care                           | 0,4              | FBS (mmol/L)<br><br>Diabetes-specific-QoL questionnaire  | -23.54**<br><br>Overall score +11.16**   | NR             |
| Sridhar et al. <sup>30</sup><br>CRT, India | 105 Indian, 57-65 y/o with T2DM for mean 7 yrs, comorbidity: no    | 52 wk supervised AE: cycling or treadmill for 60 mins, x5/wk, intensity: NR  | Usual care                           | 0,52             | HbA1c%<br>SBP (mmHg)<br>DBP (mmHg)<br>HRV (millisecond)  | -2.2**<br>-8.7*¥<br>-5.8*¥<br>+3.47**  | NR             |
| Guglani et al. <sup>31</sup><br>CRT, India | 102 Indians, 40-70 y/o with T2DM for >1 y. Comorbidity: no         | 16 wk supervised AE: walking with pedometer for 30-40 mins, x5/wk, Intensity: PRE at 12-14                                 | 1-Usual care<br><br>2-16 w pedometer | 0,16             | ADDQoL (leisure activity, working life, long distance journey, holiday, do physically, family, social life, close personal relationship, sex life, physical appearance, self-confidence, motivation, people general reaction, future, financial situation, living condition, dependence, freedom to eat, freedom to drink,<br><br>GWBS <sup>††</sup> | (-0.9**, -1.4**, -0.18, -0.3**, -1.8**, -1**, -0.5**, -0.07**, -0.1**, -1**, -0.9**, -0.5**, -0.26**, -0.7**, -0.6**, 0.7**, 0.5**, -0.7**, 0) | NR             |
| Shenoy et al. <sup>32</sup><br>CRT, India  | 40 Indians, 40-70 y/o with T2DM for 1-10 years, Comorbidity: No    | 8 wk supervised AE: walking using heart-rate monitor and pedometer for 35-40 min, x5/wk Intensity: 50-70% of maximum heart | Usual care                           | 0,8              | HBA1c%<br>FBG(mmol/L)<br>DBP (mmHg)<br>SBP (mmHg)<br>BMI (kg/m <sup>2</sup> )<br>GWBS  | -0.75**<br>-76.4**<br>-10.8**<br>-3.3**<br>-1.1*<br>+6.5**   | NR             |

|   |   | rate.   |                              |        |   |   |      |
|---|---|---|------------------------------|--------|---|---|------|
| Dixit et al. <sup>34,33</sup><br>€                  | 87 Indians, 40-54 y/o, with T2DM for mean: 5.4-6.8 yrs, comorbidity: peripheral neuropathy      | 8 wk supervised AE: treadmill for 30-45 min, x3-6/wk intensity: 40- 60% of heart rate reserve and PRE at (12-14) + diet & Education | Usual care +Education & diet | 0,8    | Neuropathy Qol<br>FBS (mmol/l)<br>PPBS (mmol/l)<br>BMI (kg/m <sup>2</sup> )<br>hip-circumference (cm)<br>hip-waist-ratio<br>MDNS<br><b>nerve conduction for peroneal and sural nerve:</b><br>Latency (millisecond)<br>Duration (millisecond)<br>Amplitude (milivolt),<br>Conduction velocity (meter/second) | -8.44**<br>-29**<br>-65.6**<br>-0.03<br>+0.33<br>-0.01<br>-5.54**<br><br>+0.3<br>+0.77<br>+0.5<br>+3.08** | NR   |
| Seshadri et al. <sup>35</sup><br>CCT, India         | 18 Indians, > 60 y/o, with T2DM for,[duration: NR], Comorbidity: obesity & physical limitations | 24 wk unsupervised home based AE: walking for 5mins per hour for most waking hours, x7/wk Intensity: Low                            | Usual care                   | 0,24   | HbA1c(%)<br>Weight (2.4kg)<br>6-M-W (m)<br>QOL-EQ-5D  | -1.33**<br>-2.4*<br>+67*<br>+13.6*  | NR   |
| Nayak et al. <sup>36</sup><br>CCT, India            | 20 Indians, 45-60 y/o, with T2DM for NR, Comorbidity: no  | 6 wk supervised AE: treadmill for 60 mins, x5/wk, Intensity: PRE at 13-14   | Usual care                   | 0,6    | FBS (mmol/l)<br>PPBS (mmol/l)   | -39**<br>-44.6**  | None |
| Shakil et al. <sup>37</sup><br>CRT, Pakistan        | 102 Pakistani, mean 54 y/o with T2DM for [duration: NR] Comorbidity: no                         | 25 wk supervised AE: treadmill, progressed from 10 to 50 mins, x3/wk Intensity: NR  | Usual care                   | 0,25   | HDI (mmol/l)<br>LDL(mmol/l)   | +4.77**<br>-15.92**   | NR   |
| Arora et al. <sup>23,24</sup><br>€<br>Shenoy et al. | 30 Indians, 40-70 y/o, with T2DM for > 6 months,  | 1) 16 wk Supervised RE: weight-lifting  | Usual care                   | 0,8,16 | <b>RE:</b> HbA1c(%)<br>FBS (mg/dl)<br>SBP(mmHg)   | -1.83***<br>-69**<br>-9***  | none |

|   |   |   |                |      |  |   |   |                          |
|---|---|---|----------------|------|--|---|---|--------------------------|
| CRT, india  | Comorbidity: no   | TMMG, 3 sets, 10 reps, x2/wk.<br>Intensity: 60- 100% of 1RM   |                |      |  | Muscle strength (N)<br>DBP (mmHg)<br>BBSS<br>at wk 8: GWBS<br>Total-c (mg/dl)***<br>HDL(mg/dl)<br>TG (mg/dl)<br>BMI (kg/m <sup>2</sup> )<br>AE: HbA1c(%)<br>FBS (mg/dl)<br>BBSS<br>BP (mmHg)<br>Muscle strength (N)<br>At w 8: GWBS<br>Total-c (mg/dl)<br>HDL(mg/dl)<br>TG(mg/dl)<br>BMI(kg/m2) | +33.7**<br>-8***<br>+3**<br>+4***<br>-25***<br>+1<br>-40<br>-0.2<br>-1.33**<br>-26**<br>+3**<br>-3, -1**<br>+31**<br>+1**<br>-11**<br>+2<br>-11<br>-0.4 |                          |
| Bashyal et al. <sup>19</sup><br>CRT, India              | 28 Indians 45-65 y/o with T2DM for NR, Comorbidity: NR              | 4 wk Supervised RE using swiss-ball TMMG, volume: NR, x3/wk, Intensity: NR.                           | RE- Thera-band | 0, 4 |  | I: FBS (mmol/l)<br>SF-36<br>C: FBS(mmol/l)<br>SF-36   | -15.22*<br>+9.35*<br>C: -8.71*<br>+3.25*  | NR                       |
| Hariharasudha & Varunkumar. <sup>20</sup><br>CRT, India | 80 Indians, 30-60 y/o with T2DM for [Duration: NR], comorbidity: no | 12 wk Supervised RE using swiss-ball TMMG, 3 sets/ 5 reps, x3/wk, Intensity: holding for 0-10 seconds | Usual care     | 0,12 |  | I: HbA1c (%)<br>FBS (mg)<br>PPBS (mg)<br>WC (cm)<br>C: no significant changes   | ¥<br>-1.41*<br>-22.05*<br>26.12*<br>-2.23*  | Two hypoglycaemic events |
| Subarmanian & Venkatesan. <sup>21</sup><br>CRT, India   | 60 Indians, 30-60 y/o with T2DM for [duration: NR] Comorbidity: no  | 12 wk Supervised RE using swiss-ball TMMG, 3 sets/5 reps, x3/wk Intensity: per guidelines of          | Usual care     | 0,12 |  | I: Hba1C (%)<br>BMI(kg/m2)<br>C: no significant changes   | ¥<br>-0.55*<br>-1.5*  | major: no<br>Minor: NR   |

| ACSM  |   |  |   |      |  |  |                                    |
|---|---|--|---|------|--|--|------------------------------------|
| Hameed et al. <sup>22</sup><br>CRT, India           | 48 Indians, 35-55 y/o, with T2DM for >6 months<br>Comorbidity: no   | 8 wk Supervised, 8 wk, RE using weight machine<br>TMMG, 3 sets/10reps/ Rest 2 mins, x2-3/wk based on participants' preference,<br>Intensity: 65- 70% of 1-RM | Sham exercise                                     | 0,8  | Hba1c(%)<br>HDL-C(mmol/l)<br>TC(mmol/l)<br>TG (mmol/l)<br>LHL-c (mmol/l)<br>SBP (mmHg)<br>DBP (mmHg)<br>Weight (kg)<br>WC (cm)<br>Muscle strength (kg) | -0.62**<br>+0.11**<br>+0.01<br>-0.02<br>-0.3<br>-3.04<br>-1.59<br>+0.25<br>-1.84**<br>+16.08**     | “few instances of muscle soreness” |
| Subramanian et al. <sup>25-28</sup> €<br>CRT, India | 100 Indians, 30-60 y/o, with T2DM, [duration: NR],<br>Comorbidity: hypertension                               | 12 wk Supervised RE using swiss-ball<br>TMMG, volume: NR, x3/wk<br>intensity: per ACSM & ADA guidelines  | Usual care  | 0,12 | I: IHbAc1(%)<br>SBP(mmHg)<br>DBP(mmHg)<br>14 items-QOL<br>BMI (kg/m <sup>2</sup> )<br>WC<br>C: IHbAc1<br>SBP, DBP<br>14 items of QOL,<br>BMI<br>WC     | ¥<br>-0.57*<br>-2*<br>-4*<br>+13*<br>1.46*<br>-3.56*<br>+0.28<br>+5 ↓,+1 ↓<br>+1<br>+0.26<br>+0.22 | Few hypoglycemic events            |
| Natesan et al. <sup>16</sup><br>CRT,USA             | 28 (1 Pakistani, 1 Bangladeshi, 26 Indians), 18-85 y/o with T2DM for approximately 7.5 yrs<br>Comorbidity: no | 8 wk Supervised CE: Bollywood & weight lifting for 60 mins, x2/wk, intensity: NR   | Usual care  | 0,8  | HBA1c<br>Weight<br>BMI   | -0.18**<br>-0.26<br>-0.11  | NR                                 |
| Paul & Mary <sup>17</sup><br>CRT, India             | 30 Indians, 16 M, 14 F, 45-64 y/o, with T2DM for > 5 yrs.<br>Comorbidity:                                     | 10 wk supervised, CE: (different AE & RE: swiss-ball) for 60 mins, x3/wk   | Supervised, 10 w, AE: (different AE, 1 hour, 3/w, | 0,10 | CE: FBS (mg/dl)<br>SF-36 (physical health problems, limitations due to physical health, limitations due to emotional                                   | -36.4**<br>(+23.82*,+65.33*,+72.67*, +21.46*,+20.33*, +12.5*,                                      | NR                                 |

|                                  |  |   |                        |      |  |  |    |
|----------------------------------|--|---|------------------------|------|--|--|----|
|                                  | no   | Intensity: NR   | [intensity: NR]        |      | problem, Energy& fatigue, emotional wellbeing, social functions, pain, general health).  | +16.94*, +29.33*)  |    |
|                                  |  |   |                        |      | <b>AE:</b> FBS (mg/dl)   |  |    |
|                                  |  |   |                        |      | SF-36 (physical health problems, limitations due to physical health, limitations due to emotional problem, Energy& fatigue, emotional wellbeing, social functions, pain, general health) | -24*<br>(+9.02*,+42*, 49.33*,+5.1*, +7.93*, +4.03, +6.84*, +6.87*) |    |
| Subramanian et al. <sup>18</sup> | 100 Indians, 30-60 y/o, with T2DM, [duration: NR].                                     | 24 wk supervised CE: (AE: x3/wk + RE:2/w) [duration: NR], intensity: per guidelines of ACSM and ADA | Usual care             | 0,24 | <b>I:</b> HbA1c(%)<br><b>WC</b> (cm)<br><b>C:</b> HbA1c (%)<br><b>WC</b> (cm)  | ¥<br>-1.23*<br>7,98*<br>+0.63 <sup>↓</sup><br>+5.46 <sup>↓</sup>   | NR |
| Majeed et al. <sup>38</sup>      | 32 Indians, 55-75 y/o with T2DM for [duration: NR]. Comorbidity: peripheral neuropathy | 6 wk Supervised balance Exercise for 30min, x3/wk, [intensity: NR]                                  | Usual care + education | 0,6  | <b>I:</b> Timed-up & go (s)<br>6-M-W (m)<br><b>C:</b> no significant change  | ¥<br>-2.075*<br>+1.34  | NR |

**Abbreviations:** €: published in more than one article; **M:** male; **F:** female; **wk:** week; **NR:** not reported; **AE:** aerobic exercise; **RE:** resistance exercise; **CE:** combined exercise; \*: significant improvement compared to baseline, \*\*: significant improvement compared to a control; ↓: deteriorated significantly compared to baseline; ¥: no between-group analysis reported; **I:** intervention group; **C:** control group; yrs: years; **DBP:** diastolic blood pressure, **SBP:** systolic blood pressure **QoL:** quality of life; **ADDQoL:** The Audit of Diabetes-Dependent Quality of Life **6-M-W:** 6 Minutes-walk **HDL:** High-density lipoprotein; **LDL:** low-density lipoprotein; **T-cholesterol:** Total-cholesterol; **GWBS:** General health-wellbeing scale; **BBS:** Berg Balance scoring Scale; **yrs:** years; **y/o:** years old; **ACSM:** American College of Sports Medicine; **TMMG:** targeting Main muscle groups; **1-RM:** one-repetition maximum; **RPE:** the Rating Perceived Exertion Scale, **min:** minute.

**Numbers represent change from baseline to post intervention in the exercise groups unless stated otherwise**

Table 2. PEDro scores

| Author | Eligibility<br>Criteria | Random<br>Allocation | Concealed<br>Allocation | Baseline<br>Comparability | Participant<br>Blinding | Therapist<br>Blinding | Assessor<br>Blinding | < 15%<br>Dropout | Intention<br>to Treat | Between-<br>Group | Point<br>Estimate | Total<br>(out of |
|--------|-------------------------|----------------------|-------------------------|---------------------------|-------------------------|-----------------------|----------------------|------------------|-----------------------|-------------------|-------------------|------------------|
|--------|-------------------------|----------------------|-------------------------|---------------------------|-------------------------|-----------------------|----------------------|------------------|-----------------------|-------------------|-------------------|------------------|

|   |   |   |   |   |   |   |   |   |   |   | Difference and Variability | 10) |
|---|---|---|---|---|---|---|---|---|---|---|----------------------------|-----|
| Natesan et al. <sup>16</sup>                              | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1                          | 6   |
| Paul & Mary <sup>17</sup>                                 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1                          | 4   |
| Subramanian et al. <sup>18</sup>                          | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1                          | 2   |
| Bashyal et al. <sup>19</sup>                              | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1                          | 4   |
| Hariharasudha & Varunkumar <sup>20</sup>                  | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1                          | 4   |
| Subarmanian & Venkatesan <sup>21</sup>                    | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1                          | 3   |
| Hameed et al. <sup>22</sup>                               | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1                          | 6   |
| Arora et al. <sup>23</sup><br>Shenoy et al. <sup>24</sup> | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1                          | 5   |
| Subramanian et al. <sup>25-28</sup>                       | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1                          | 4   |
| Rekha et al. <sup>29</sup>                                | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1                          | 5   |
| Sridhar et al. <sup>30</sup>                              | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1                          | 4   |
| Guglani et al. <sup>31</sup>                              | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 1                          | 5   |
| Shenoy et al. <sup>32</sup>                               | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1                          | 6   |
| Dixit et al. <sup>33,34</sup>                             | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1                          | 6   |
| Seshadri et al. <sup>35</sup>                             | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1                          | 2   |
| Nayak et al. <sup>36</sup>                                | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1                          | 4   |
| Shakil et al. <sup>37</sup>                               | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1                          | 4   |
| Majeed et al. <sup>38</sup>                               | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1                          | 3   |

Table 3. Effects of different exercise programs

|   | Hba1c | blood pressure | blood lipids | anthropometrics | muscle strength | balance/functional mobility | quality of life and well-being |
|---|-------|----------------|--------------|-----------------|-----------------|-----------------------------|--------------------------------|
| <b>Aerobic</b>  | √ √√√ | √√√            | √√           | x               | √               | √                           | √√√√                           |
| <b>Resistance</b>   | √√    | √√             | √√           | √               | √√              | √                           | √                              |
| <b>Combined</b>   | √     | NI             | NI           | NI              | NI              | NI                          | √                              |
| <b>Balance</b>  | NI    | NI             | NI           | NI              | NI              | √                           | NI                             |
| <b>√: a study reporting statistically significant improvement; X: Effect of exercise investigated but no significant improvement was reported; NI: The effect of exercise has not been investigated</b> |       |                |              |                 |                 |                             |                                |



## Appendix one: Search strategies

### MEDLINE and Embase were searched using the Ovid

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1. exp Exercise/ or exp Exercise Therapy/ or exercise.mp. or Circuit-Based Exercise/ or exp Exercise Movement Techniques/ (313503)
2. ("aerobic exercise" or "aerobic training" or (aerobic adj 2 program\*) or walking or treadmill or "circuit training" or "circuit exercise" or swimming or ergometer or bike or running).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonymy]
3. ("balance training" or "functional training").mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]
4. ("thera\*band" or "resistance\*band" or "weight lifting" or "gym machine" or "physio\*ball" or "swiss\*ball" or "balance\*ball" or "Elastic\*band" or "resistance training" or "strengthening training" or "strengthening exercise" or "resistance exercise").mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]
5. "physical activity".mp.
6. 1 or 2 or 3 or 4 or 5
7. exp Diabetes Mellitus, Type 2/ or "non\*insulin\*dependent".mp.
8. "Type II diabetes".mp.
9. 7 or 8
10. exp Asian Continental Ancestry Group/ or exp Ethnic Groups/ or south asian.mp.
11. (India\* or Pakistan\* or Bangladesh\* or "Sri Lank\*" or Nepa\* or (south adj2 asia\*)).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]
12. 10 or 11
13. 6 and 9 and 12

## Cinhal

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1. (MH "Exercise+") OR "exercise" OR (MH "Resistance Training") OR (MH "Therapeutic Exercise+") OR (MH "Group Exercise") OR (MH "Sport Specific Training")
2. (MH "Aerobic Exercises+") OR ""aerobic exercise" OR "aerobic training" OR (aerobic N3 program\*) OR walking OR treadmill OR "circuit training" OR "circuit exercise" OR swimming OR ergo\*meter OR bike OR running"
3. (MH "Balance Training, Physical") OR (MH "Functional Training") OR ""balance training" OR "functional training""
4. (MH "Resistance Training") OR (MH "Muscle Strengthening") OR (MH "Body-Weight-Supported Treadmill Training") OR ""thera\*band" OR "resistance\*band" OR "weight lifting" OR "gym machine" OR "physio\*ball" OR "swiss\*ball" OR "balance\*ball" OR "Elastic\*band" OR "resistance training" OR "strengthening training" OR "strengthening exercise" OR "resistance exercise""
5. (MH "Physical Activity")
6. S1 OR S2 OR S3 OR S4 OR S5
7. (MH "Diabetes Mellitus, Type 2") OR "type 2 diabetes"
8. "non\*insulin\*dependent"
9. "Type II diabetes"
10. S7 OR S8 OR S9
11. (MH "Asians") OR "south asian"
12. india\* OR Pakistan\* OR Nepal\* OR Bangladesh OR "sri lanka\*"

1. #1- MeSH descriptor: [Motor Activity] 1 tree(s) exploded
2. #2- MeSH descriptor: [Exercise] explode all trees
3. #3- (aerobic near/2 exercise) or (aerobic near/2 training) or (aerobic near/2 program?) or walking or treadmill or (circuit near/2 training) or (circuit near/2 exercise) or swimming or ergometer or bike or running
4. #4- (balance near/2 training) or (functional near/2 training)
5. #5- theraband or resistanceband or (weight near/2 lifting) or (gym near/2 machine) or physio?ball or swiss?ball or balance?ball or Elastic?band or (resistance near/2 training) or (strengthening near/2 training) or (strengthening near/2 exercise)
6. #6- #1 or #2 or #3 or #4 or #5
7. #7- (south near/2 asia?)
8. #8- india?
9. #9- pakistan?
10. #10- (sri lanka?)
11. #11- bangladesh
12. #12- nepal?
13. #13- #7 or #8 or #9 or #10 or #11 or #12
14. #14- MeSH descriptor: [Diabetes Mellitus, Type 2] explode all trees
15. #15- non?insulin?dependent
16. #16- #14 or #15
17. #17- #6 and #13 and 16

Pedro:

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Exercise AND Diabetes