EFFECTOFRESISTEDBLOODFLOWRESTRICTION IN PATIENTS WITH TYPEIIDIABETES

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CHAPTER1INTR ODUCTION

Diabetes mellitus type II (T2DM) is a chronic metabolic condition characterized by insulin resistance and relative insulin deficiency, leading to hyperglycemia and multisystemic complications **(American Diabetes Association [ADA], 2024).**

Type 2 diabetes mellitus (T2DM) is a rapidly growing public health concernworldwide.AccordingtotheInternationalDiabetesFederation(IDF), approximately537millionadultsaged20–79yearswerelivingwithdiabetes globallyin2021,andthisnumberisexpectedtoriseto643millionby2030and 783millionby2045.Notably,morethan90%ofthesecasesareclassifiedas type2diabetes**(IDF,2021).**

Type2diabetesmellitus(T2DM)hasasignificantdetrimentaleffecton muscle strength, balance, and overall physical function, primarily due to insulin resistance, chronic inflammation, mitochondrial dysfunction, and impairedneuromuscularcoordination.Thesephysiologicalchangesresultin muscle atrophy—particularly of type II fibers—along with reduced proprioceptionanddiminishedfunctionalperformance**(Liuetal.,2024).**

Naruseetal.(2024)foundthatadultswithT2DMhadsignificantlylower gripstrength(34.2±9.8kg),slowerwalkingspeed(1.3±0.2m/s),andshorter one-legstandingtime(~30s),comparedtohealthycontrols.

Similarly, **Alahmari andReddy (2024)**examinedlower-limb strengthand proprioceptioninT2DMpatients,reportingsignificantlyreducedisokinetic

kneeextension/flexionstrength(12.9–26.4Nmdifference),impairedjoint positionsense,anddecreasedlimitsofstability(P<.001),whichcollectively reflectimpairmentsinposturalbalanceandfunctionalmobility(**Alahmaris Reddy,2024).**

In addition, sarcopenia—the progressive loss of muscle mass and function—is notably more common among those with T2DM. A 2021 meta-analysis by Zhu et al. found that sarcopenia affects approximately 18% of adultswithT2DM(95%CI:15–22%),withhigherprevalenceinolderindividuals andthosewithlongerdiseaseduration.Sarcopeniacontributestoreduced mobility, slower gait, and impaired ability to perform daily tasks, increasing the riskoffallsandfrailty**(Zhuetal.,2021).**

Standardexerciseprogramsforindividualswithtype2diabetesmellitus (T2DM)typicallyinvolveacombinationofaerobic,resistance,andflexibility training to improve glycemic control, cardiovascular fitness, muscle strength, andoverallmetabolic health.Accordingto theAmericanDiabetesAssociation (2023)andtheAmericanCollegeofSportsMedicine(2022),adultswithT2DM areadvisedtoperformmoderate-intensityaerobicactivityforatleast150 minutesperweek,distributedoveratleastthreedays,withnomorethantwo consecutivedaysofinactivity.Resistancetrainingshouldbeperformedtwoto three times weekly using moderate loads (50–70% of one-repetition maximum),targetingmajormusclegroups.Flexibilityandbalanceexercises arealsoencouraged,particularlyinolderadultsorthoseatincreasedriskof falling**(Colbergetal.,2016).**Thesestructuredprogramshavedemonstrated effectiveness in reducing HbA1c, improving insulin sensitivity, lowering cardiovascularrisk,andenhancingphysicalfunction.Moreover,individualized exercise prescription—tailored to a patient's physical capacity, medical status, and lifestyle—has been shown to improve adherence and optimize outcomesindiabetescare**(Doupis,Karras,sAvramidis,2021).**

Resistance training (RT) is widely recognized as a key non-pharmacological intervention for individuals with type 2 diabetes mellitus (T2DM),offeringsignificantbenefitsinimprovingglycemiccontrol,muscle strength,andmetabolichealth.AsystematicreviewbyWanandSu(2024) found that resistance training significantly reduced HbA1c (−0.50%) and fastingglucose levels, with greater benefits seenin moderate-to-high intensity programs, improving body composition, and enhancing cardiovascular markers. However, these high-load protocols may not be feasible for all patients.ManyindividualswithT2DMexperiencebarriersthatlimittheirability toparticipate inorsustainconventionalRTprograms.Accordingto**Shawetal. (2023),**thesebarriersincludephysicallimitations(e.g.,jointpain,fatigue), psychologicalfactors(e.g.,fearofinjury,lowmotivation),andenvironmental orsocioeconomicchallenges(e.g.,care-givingresponsibilities,limitedaccess to exercise facilities). These limitations highlight the need for alternative trainingmethodsthataresafe,low-load,andaccessibleforindividualswith T2DM,especiallythosewithcomorbiditiesorreducedfunctionalcapacity.

BloodFlowRestriction(BFR)trainingisaformoflow-intensityexercise performedwithexternalcompression-usuallycuffsorelasticbands-appliedto thelimbs.Thisrestrictionpartiallylimitsarterialbloodflowandfullyrestricts venous return, leading to a hypoxic environment in the working muscles. Despitethelowerloadsused,thephysiologicalmechanismsofBFRtraining involvemetabolicstress,increasedmotorunitrecruitmentparticularlyoffast-

twitchfibersandcellularswelling,evenatlowloads**(Pattersonetal.,2022; Hughesetal.,2021;Scottetal.,2022).**

Statementoftheproblem:

Isthereasignificanteffectofaddingresistedbloodflowrestriction(BFR) training to a standard therapeutic exercise program on muscle strength, balance,andphysicalfunctioninpatientswithtype2diabetesmellitus?

Purposeofthestudy:

Thisstudywillbeconductedtoinvestigatetheeffectofaddingresistedblood flowrestriction(BFR)trainingtoastandardtherapeuticexerciseprogramon muscle strength, balance, and physical function in patients with type 2 diabetesmellitus.

Significanceofthestudy:

Researchindicatesthatpatientswithtype2diabetesmellitus(T2DM), particularlythosewithlong-standingdiseaseduration,frequentlyexperience reduced muscle strength, impaired proprioception, and compromised balance control. These neuromuscular deficits are largely attributed to peripheralneuropathy,microvascularcomplications,andprogressivemuscle atrophy **(Allet et al., 2010; Park et al., 2006)**. As a result, individuals with T2DM faceanelevatedriskoffalls,mobilityimpairments,andfunctionaldisability—factorsthatsignificantlyreducequalityoflifeandincreasetheriskoffrailty.

Conventional resistance training is widely recognized for its role in improving muscle strength, glycemic control, and physical function in individualswithT2DM**(Colbergetal.,2016).**However,manypatientsface physicalandmedicalbarrierstoperforminghigh-intensitystrengthtraining, suchasjointdiscomfort,fatigue,cardiovascularlimitations,orfearofinjury. Thesechallengesoftenreduceadherenceandlimitaccesstothefullbenefits oftraditionaltrainingapproaches**(Shawetal.,2023).**

Blood flow restriction (BFR) training has emerged as a promising alternative.BFRinvolveslow-loadresistanceexercisescombinedwithpartial vascularocclusionusingexternalcuffs,whichinduceslocalizedhypoxiaand metabolic stress. This method has been shown to stimulate muscle hypertrophy and strength gains comparable to high-load training but with substantiallylowerjointandcardiovascularstrain**(Lixandrãoetal.,2015; Pattersonetal.,2022).**Recentclinicalresearchhasdemonstratedthat BFR trainingiseffectiveinimprovingstrengthandfunctionalperformanceinolder adultsandpatientswithchronicdiseases**(Centneretal.,201G;Maetal., 2024).**

DespitegrowingevidencesupportingBFRingeneralclinicalpopulations, its application in individuals with T2DM remains limited, particularly concerning outcomes related to postural control and functional mobility. Giventhecloserelationshipbetweenmusclestrength,proprioception,and balanceregulation,BFRmayofferdualbenefitsforaddressingbothstrength

deficits and balance impairments in diabetic populations **(Yamada et al., 2024;AlahmarisReddy,2024).**

Thisstudyseekstofillthisresearchgapbyevaluatingthefunctional effectsof integrating BFRintoa standard exerciseprogramfor individualswith T2DM.Identifyingasafe,effective,andaccessiblealternativetoconventional resistancetrainingis critical,especiallyforpatientswithcomorbiditiesor reducedfunctionalcapacity.Thefindingsofthisstudyhavethepotentialto informclinicalrehabilitationpracticesbyincorporatingBFRasaviabletoolto enhancemusclestrength,reducefallrisk,andimprovelong-termphysical independenceinpatientswithtype2diabetes.

Delimitations:

Thisstudywillbedelimitedto:

1- Adultparticipants(bothmalesandfemales)
2- Participant age will be ranged from 50-60 years old with a confirmeddiagnosisoftype2diabetesmellitus(T2DM)foratleast 5years.
3- Participants who are medically stable and physically able to performlow-to-moderateintensityexercise.
4- Patients who are not currently engaged in any structured resistanceoraerobicexerciseprogram.
5- Interventionwilllastfor12weeksandwillbeperformedunder supervisedoutpatient conditions.

Basicassumption:

Itwillbeassumedthat:

1- Allparticipantswillfollowinstructionsandattendexercise sessionsregularly.
2- Allparticipantswillbecooperative.
3- Allparticipantswillfollowtheinstructionsgivenduringallsteps of assessment and treatment.
4- Themeasurementtoolsusedforassessment(e.g.,handheld dynamometers,balancetests,andphysicalperformancetests) arevalidandreliable.
5- Environmentalandpsychologicalconditionsduringtestingwillbe consistentforallparticipants.
6- Participantswillprovidehonestresponsesandmaximaleffort duringassessments
7- Nosignificantexternalfactors(e.g.,changesinmedicationor diet) will interfere with the training effects during the intervention period.

Hypothesis:

Nullhypothesis:There isnosignificantdifference inmuscle strength, balance,orphysicalfunctionbetweentypeIIdiabeticpatientswho followaconventionalexerciseprogramandthosewhofollowthe sameprogramcombinedwithbloodflowrestrictiontraining.

CHAPTERIILITE
RATUREREVIEW

Type 2 diabetes mellitus (T2DM) is a chronic metabolic disorder characterized by insulin resistance and a relative deficiency in insulin secretion. Beyond glycemic abnormalities, T2DM is associated with multisystemcomplicationsthatsignificantlyimpairphysicalfunction.These impairments manifest as reduced muscle strength, poor balance, and diminishedfunctionalmobility,ultimatelyincreasingtheriskofdisability,falls, and loss of independence in affected individuals **(American Diabetes Association[ADA],2024).**

Functional impairments are highly prevalent among individuals with T2DM.Arecentmeta-analysisreportedthatolderadults with T2DMhave a63% higher risk of falls compared to non-diabetics (hazard ratio=1.63; odds ratio=1.59)**(Zhaoetal.,2024)**.Similarly,alargeprospectivecohortstudyin China found that community-dwelling older adults with T2DM had a 78% greaterriskofexperiencingafallovertwoyearscomparedtonon-diabetic peers**(Linetal.,2024).**Thesefindingshighlighttheurgentneedforearly intervention strategies targeting strength and balance in the diabetic population.

The pathophysiological mechanisms behind physical decline in T2DM include chronic hyperglycemia, mitochondrial dysfunction, systemic inflammation, and impaired neuromuscular signaling. These factors contributetoacceleratedmuscleatrophy,particularlyintypeIIfibers,reduced

proprioceptive feedback, andaltered motorcontrol**(Alahmari s Reddy, 2025).** Collectively, these changes compromise the capacity to perform daily activitiesandelevatetheriskofadverseeventssuchasfallsandfractures.

Muscle weakness is a well-documented consequence of T2DM and is linkedtomultiplemechanismsincludinginsulinresistance,reducedanabolic signaling, and capillary rarefaction in skeletalmuscle. Studies haveshownthat individuals with T2DM demonstrate significantly lower muscle strength, particularlyinthelowerextremities,whencomparedtoage-matchedhealthy peers **(Yamada et al.,2024).** Thismuscle weakness isexacerbatedbyphysical inactivity,neuropathy,andsarcopenia.

Sarcopenia, defined as the age-related loss of muscle mass and function, is more prevalent among individuals with T2DM. A recent meta-analysisrevealedthatapproximately18%ofadultswithT2DMareaffectedby sarcopenia,withanevenhigherprevalenceinolderadultsandthosewithpoor glycemic **control (Zhu et al., 2021).** Decreased muscle strength directly impactsfunctionalperformance,makinginterventionsaimedatimproving musclemassandforcegenerationcriticalindiabetescare.

Recent evidence suggests that sarcopenia associated with T2DM representsadistinctphenotype,differingfrombothage-relatedsarcopenia and disuse muscle atrophy. According to **Liu et al., (2024),** T2DM-related sarcopeniaischaracterizedbypersistenthyperglycemia,chroniclow-grade inflammation,insulin resistance,mitochondrialdysfunction,andimpaired protein synthesis, all of which accelerate muscle degradation and inhibit repair.Thesemechanismsleadtoselectivelossoftype IImusclefibers,

reducedcapillarydensity,andimpairedneuromuscularjunctionintegrity—ultimatelyresultingingreatermuscleweaknessandfunctionallimitationthan observedinnon-diabeticagingpopulations.

Balance dysfunction in T2DM is a multifactorial issue stemming from peripheralneuropathy,impairedproprioception,andvestibulardeficits.The deteriorationofsensoryfeedbackfromthefeetandjointshinderspostural controlandreactiontime,contributingtoaheightenedriskoffalls(**Alahmari sReddy, 2025).** Quantitative assessments have shown that diabetic individualshaveshorterone-legstandingtimes,increasedposturalsway,and reducedlimitsofstabilitycomparedtohealthycontrols**(Yamadaetal.,2024).**

Thesedeficitsarefurtheraggravatedbymuscleweaknessanddelayed neuromuscular responses. Improving lower-limb strengthandproprioception is therefore fundamental to restoring balance and preventing falls in this population

T2DMsignificantlyimpairsphysicalfunction,includingwalkingability, stairclimbing,sit-to-standtransitions,andendurance.Limitationsinthese areas reduce quality of life and increase dependency. A growing body of literaturelinkspoorglycemiccontrolandsedentarybehaviorwithdeclining physicalperformance.

Functional impairments in T2DM are not only associated with musculoskeletal deficits but also with cardiovascular limitations, such as reduced aerobic capacity and endothelial dysfunction **(Ma et al., 2024).** Addressing these issues through structured exercise programs is a cornerstoneofnon-pharmacologicaldiabetesmanagement.

Resistance training (RT) has been consistently recommended for individualswithT2DMduetoitsabilitytoimproveglycemiccontrol,insulin sensitivity,andmusclestrength.RTalsopositivelyinfluenceslipidprofiles, inflammatorymarkers,andoverallmetabolichealth**(Panetal.,2018).**High-intensity RT, in particular, has demonstrated superior effects on reducing HbA1candincreasingleanbodymasscomparedtomoderateorlow-intensity programs.

However,notallpatientscantoleratehigh-loadRTduetojointpain, fatigue,comorbidities,orlimitedmobility.Thesebarriersoftenhinderlong-termadherenceandnecessitatealternativemethodsthatprovidecomparable benefitswithreducedmechanicalstrain**(Shawetal.,2023).**

Bloodflow restriction(BFR) training is an innovativemethodinvolving the application of external pressure—typically via cuffs or elastic bands—to partially restrict arterial inflow and fully occlude venous return in the exercising limb.Thisinducesahypoxicandacidicintramuscularenvironment,enhancing anabolicsignalingandrecruitmentoffast-twitchfibersevenunderlowloads **(Loennekeetal.,2020).**

TheneuromusculararandcellularadaptationsinducedbyBFRtrainingare largely driven by metabolic stress, intramuscular hypoxia, and cellular swelling,whichcollectivelyenhancemuscleproteinsynthesis.**Scottetal. (2022)** highlighted that BFRpromotesearly recruitment oftype II (fast-twitch) motor units, increases motor neuron excitability, and stimulates anabolic pathwayssuchasmTORC1andMAPK,evenwhenlowtrainingloadsareused. Additionally,theaccumulationofmetaboliteslikelactateandhydrogenions

triggersasystemichormonalresponse,includingelevatedgrowthhormone andIGF-1,furthersupportingmusclehypertrophyand functionalgains.These mechanismsmakeBFRparticularlyeffectiveforpopulations—likethosewith T2DM—whocannottoleratehighmechanicalloads.

BFR has gained attention for its ability to mimic the physiological benefits of high-intensity resistance training using only 20–30% of one-repetition maximum (1RM) loads. Studies have shown that BFR improves muscle strength,hypertrophy, and vascular function in variouspopulations, including olderadultsandindividualswithchronicconditionssuchasT2DM**(Yasudaet al.,2020).**

Clinicaltrials have begun toestablishthe effectiveness ofBFRtraining in individualswithT2DM.Ina24-weekrandomizedcontrolledtrial,**Maetal. (2024)** investigatedtheimpactof low-loadresistancetrainingcombined with BFRinolderadultswithtype2diabetes.Theinterventionledtosignificant improvementsinHbA1clevels,triglycerides,bodycomposition,andlower-limb muscle strength compared to baseline. The BFR group also showed greaterimprovementsinleanmassandinsulinsensitivitycomparedtothe control group performing conventional resistance training. These findings supportBFRasasafeandeffectivelow-loadalternativefordiabeticindividuals whocannottoleratehigh-loadexerciseduetofatigue,jointpain,orother complications.

Giventhehighprevalenceofphysicallimitationsamongpatientswith T2DM,integratingBFRintoexerciseregimensprovidesasafe,effective,and accessiblestrategytoenhancemuscleperformanceandphysicalfunction.By

enablinglow-loadtrainingwithhighphysiologicalstress,BFRbridgesthegap forindividualsunabletoparticipateinconventionalRT.

Furthermore,recentfindingshighlightthepotentialofBFRtrainingto improvenotonlymusclestrengthbutalsodynamicbalanceandmobility.This may be attributed to improved neuromuscular activation and increased proprioceptivedemandduringexercise**(Maetal.,2024;Yasudaetal.,2020).**

Despite its promise, most BFR research has focused on metabolic outcomes, with limited studies evaluating functional parameters such as strength,balance,anddailyactivityperformanceindiabeticpatients.This underscorestheneedforfurtherinvestigationintothefunctionalbenefitsof BFR in this population.

Thecurrentstudyaimstofillthisgapbyexploringtheimpactofadding resistedBFRtrainingtoastructuredexerciseprogramonmusclestrength, balance,andphysicalfunctioninindividualswithT2DM

Resistance exercise is a key strategy in managing type 2 diabetes mellitus(T2DM),yetmanypatientsareunabletoperformhigh-loadtraining duetomusculoskeletallimitationsordiabetes-relatedcomplications.Blood FlowRestriction(BFR)trainingoffersapromisinglow-loadalternativethat reducesmechanicalstresswhilepromotingsimilarphysiologicalbenefits.

Despite growing evidence supporting the use of BFR in T2DM, most studies focus on metabolic outcomes such as glycemic control. However, thereisalackofresearchspecificallyexaminingitsimpactonmusclestrength,

balance,andphysicalfunction—criticalareasoftenimpairedinindividuals withT2DM.

Therefore,thisstudy seeksto investigate whetherintegratingbloodflow restriction(BFR)intoastructuredlow-loadexerciseprogramcaneffectively improve muscle strength, balance, and functional performance in middle-agedadultswithT2DM.Addressingthisgapcouldoffernewclinicalstrategies to enhance physical independence and reduce fall risk in this vulnerable population.

CHAPTERIII

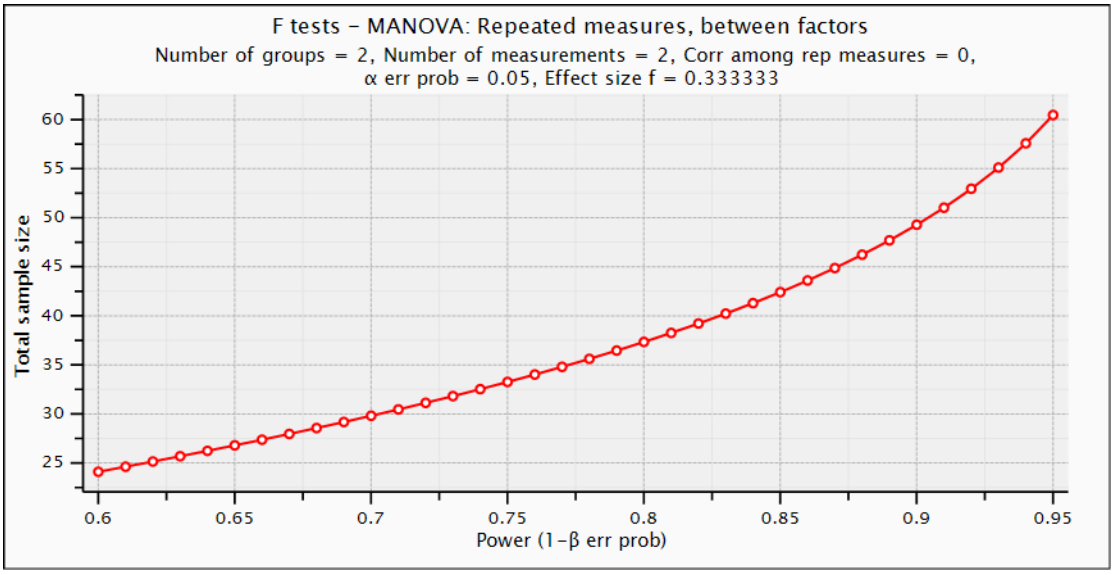
PatientandMETHODES

This current study will be designed to measure the effect of adding resisted bloodflowrestrictiontoexerciseprogramonmusclestrength,balanceandphysical function in patient with type II diabetes. This study will be conducted in outpatient clinic and Al-Ahram Canadian University, Cairo, Egypt.

Studydesign: Randomizedcontrolstudy.

Samplesize:

ThesamplesizewasobtainedusingtheF-test-MANOVA:repeatedmeasures, betweenfactorwithapowerof80%,andatypeIerrorof5%.Theeffectsize(0.34) was calculated from primary outcome (balance) depending on the data from publishedresearch**(Waleedetal.,2023).**Theminimalsamplesizewas56,andthe number was increased by 10% to accommodate for drop outs. The proper sample size was 60 subjects .For the calculations, G* Power version 3.1.9.2 (Franz Faul, Uni Kiel, Germany) was utilized.



Studydesign: Randomizedcontrolstudy.

Subject'sselection:

Thisstudywillincludeatotalofsixtyadultparticipantsdiagnosedwith type2diabetesmellitus(T2DM)foratleastfiveyears,agedbetween50and60 years.ParticipantswillberecruitedfromAl-AhramCanadianUniversityand OutpatientClinic.Afterscreeningforeligibilityandobtainingwritteninformed consent,participantswillberandomlyassignedintotwoequalgroups:

Group(A)Therapeuticgroup,(Exercise+BFRGroup):Thisgroupwill consist of30 participants who will performthe sameexercise protocol as Group B, but with the additionofbloodflow restriction (BFR)training applied to bothlowerlimbsduringtheresistanceportionofthesessionusingBFRsystem.

Group (B) Control group, (Exercise-Only Group): This group will consist of 30participantswhowillfollowastandardizedtherapeuticexerciseprogram basedontheAmericanCollegeofSportsMedicine(ACSM)guidelines.Each sessionwilllast50minutes,performedthreetimesperweekforatotalof twelveweeks.

(A) Inclusioncriteria:

1) Diagnosedwithtype2diabetesmellitus(T2DM)foratleast5years.
2) Agebetween50and60years.
3) Medically stable and cleared for participation in a low-to-moderate intensity exercise program.
4) Notcurrentlyengagedinstructuredresistancetraining.
5) Abletowalkindependentlywithoutassistivedevices.
6) BergBalanceScale(BBS)scorebetween21and40,indicatingmoderate balance impairment.

7) ShortPhysicalPerformanceBattery(SPPB)scorebetween4and9,indicating mild-to-moderate physical function limitation.
8) Quadricepsmusclestrengthof<80%ofage-predictednormalvaluesas measured by handheld dynamometer.
9) LowtomoderatephysicalactivitylevelasassessedbytheInternational Physical Activity Questionnaire (IPAQ)

(B) Exclusioncriteria:

1) Historyofrecentcardiovascularеventsoruncontrolledhypertension.
2) Peripheralarterialdiseaseordeepveinthrombosis.
3) Severediabeticneuropathyorretinopathy.
4) Musculoskeletaldisordersaffectingexerciseperformance.
5) Cognitiveimpairmentsorpsychiatricillnessinterferingwithadherenceto protocol.
6) Smokers.
7) Uncontrolleddiabetes.

(C) Ethicalconsideration:

1) Approvalofethicalcommitteeoffacultyofphysicaltherapywillbeachieved before starting the study.
2) Thestudyprocedurewillbeexplainedforalltheparticipants.
3) Confidentialitywillbeassured.
4) Allparticipantswillsignaconsentformbeforestartingofthestudyandknow about the study (aim – procedures) (appendix 1).

B.Instrumentsandmaterials.

A) Evaluating equipment: All participants will be evaluated before and after treatment protocol.

1) **Active Force 2 Handheld Dynamometer:** Muscle strength of the quadriceps and calf muscles on the dominant leg will be measured usingtheActiveForce2handhelddynamometer(Medup,Italy).This portabledigitaldeviceutilizesahigh-sensitivityloadcelltomeasure isometric muscle force in Newtons (N) and displays results via a Bluetooth-connected mobile app. It is user-friendly and has demonstrated moderate test–retest reliability in measuring lower limb muscle strength, especially knee extension, among healthy adults (Sasidharan et al., 2025).
2) **Berg Balance Scale (BBS):** Used to assess static and dynamic balance through 14 tasks. It is a reliable tool for detecting balance impairments in individuals with type 2 diabetes **(Li et al., 2025).**
3) **Short Physical Performance Battery (SPPB):** Includes three subtests: balance (three stance positions), 4-meter gait speed, and five-timeschairstand.Eachcomponentisscoredfrom0to4,witha maximum score of 12. Higher scores indicate better function. It is widely used in geriatric and chronic disease populations **(Cruz-Jentoft et al., 2019).**
4) **Fasting blood glucose level** : The Accucheck glucometer will be usedtomeasurethesubjects'fastingbloodglucoselevelsbeforeand after12weeksofexercisetrainingunderthesupervisionofamedical laboratory expert. **(American Diabetes Association, 2023).**

5) **Pulse Oximeter:** A fingertip pulse oximeter Peripheral oxygen saturation (SpO_2) and heart rate were measured using a fingertip pulse oximeter (Model: SN-A60, Version: 2.0).The device is manufacturedinChinaandisRoHS-compliant.Itwillbeusedduring each trainingsessionto monitor oxygensaturation (SpO_2) and heart rate. This ensures real-time monitoring of the participant's cardiopulmonary status and supports early detection of adverse responses, particularly during blood flow restriction training **(American Diabetes Association, 2023).**

6) **Physical Activity Assessment:** Physical activity levels of participants will be assessed at baseline using the International PhysicalActivityQuestionnaire–ShortForm(IPAQ-SF).Thisself-reported questionnaire evaluates the frequency and duration of walking, moderate, and vigorous physical activity, as well as sedentary behavior, over the previous seven days. It is widely used in clinical and research settings dueto itseaseof administration and broad applicability. For this study, the Arabic version of the IPAQ-SF will be used, which has been culturally adapted and validated in Arabic-speaking populations, demonstrating acceptable reliability and validity **(Al-Eisa et al., 2016).**

B) Therapeuticequipment:

1) **Blood Flow Restriction (BFR) System:** It includes multi-chambered elastic cuffs and a manual hand pump. The cuffs will be applied bilaterally to the proximal thighs, and inflated to 50–60% of estimated limb occlusion pressure (LOP), following the manufacturer's pressure charts and guided by participant feedback **(Loenneke et al., 2020; Patterson et al., 2019; Hughes et al., 2019).**

2) **Exercise Equipment:** All participants will use standard exercise equipmentincludingresistancebands,ankleweights,andstepplatforms. Progression will follow American College of Sports Medicine **(ACSM, 2022)** guidelines.

C) Procedureandtesting:

On approval to participate in the study, all subjects will sign an informed consent form after receiving full information on the purpose of study, procedure, possible benefits, privacy and use of data, and their rights to withdrawfromthestudywhentheywant.Ourparticipantswillundergothe following battery of evaluation:

Evaluatingprocedures:

Itwillbeperformedbeforetreatmentand12weeksaftertreatmentprogram**.**

a) Historyandphysicalexamination:

Complete history taking will be conducted to collect data about patient's general condition, current medication, measuring blood pressure and physical activity.

- **Pulseoximetry**

Pulse oximetry represents one of the most important technological advances in medicine, permitting to continuously, non-invasively and simultaneously monitorSpO_2ofhemoglobininthearterialbloodandHeartrateandrecorded at rest and submaximal exercise during exposure to various altitudes **(Dünnwald et al., 2021)**

- **ActiveForce2HandheldDynamometer:**

Muscle strength was assessed using the Active Force 2 handheld dynamometer(Medup,Italy).Thiscompactdigitaldeviceusesaloadcellto accurately capture isometric muscle force in Newtons (N). It connects via Bluetoothtoamobileapplicationthatprovidesreal-timefeedback,facilitating accurate and consistent measurements.TheActive Force2has demonstrated moderatetest–retestreliability,particularlyinassessingkneeextensionand flexionstrengthinhealthyadults(Sasidharanetal.,2025).

- **Fastingbloodsugarlevel(FBS)test**

Bloodglucoselevelat rest:The Accu-Chekglucometer willbe usedtomeasure thesubjects'fastingbloodglucoselevelsbeforeandafter12weeksofexercise training under the supervision of a medical laboratory expert. A trained medical laboratory technician will take the blood sample after an overnight fast, transportedittoastandardtertiarycarelaboratory,andthenwillbesentitto thereferrallabforanalysis.Thestudy'slaboratorytechnicianswillbeblinded beforeandaftertheintervention.**(AmericanDiabetesAssociation,2023).**

Therapeuticprocedures:

Participantsinbothgroupswillundergoasupervised,standardizedexercise program targeting lower limb strength and balance, with particular focus on the quadriceps muscles. The intervention will last for 12 weeks, with sessions conductedthreetimesperweek,eachlastingapproximately45minutes.This program is based on established guidelines from the American College of SportsMedicine(2022)andrecentevidencesupportingstructuredresistance

andbalancetraininginpatientswithtype2diabetesmellitus(**Kanaleyetal., 2022;Colbergetal.,2016).**

GroupA:Exercise+BloodFlowRestriction(BFR)

ThisgroupwillfollowthesameexerciseprotocolasGroupB,withthe additionofBloodFlowRestriction(BFR)appliedonlyduringresistance exercises.

BFRSystem: Amulti-chamberedelasticcuffsystemwithamanualhandpump willbeused.Cuffswillbeplacedbilaterallyattheproximalthighsandinflated to50-60%ofestimatedlimbocclusionpressure(LOP).Inflation willfollow manufacturerguidelinesandbeguidedbyparticipanttoleranceandsafety **(Loennekeetal.,2020;Pattersonetal.,201G).**

Application:

BFRcuffswillbeappliedimmediatelypriortotheresistancephase.

Pressure will be maintained throughout resistance exercises and released duringrest,balance,andcool-downphases.

TheKAATSUAirBand (Producttype:C3,USA)willbe tied tothemostproximal endofthesubject'slowerlimb,withatightnessthatcouldaccommodateone finger.Arterialocclusionpressure(AOP)inthelowerlimbwasestimatedusing a predictive equation developed by Wedig et al. (2024). This formula was chosenduetoitshigherpredictiveaccuracy,internalvalidation,andsuitability forseatedBFRapplicationsusingan18cm-widecuff.Theequationusedisas follows

{AOP}=-12.179+(1.084{ThighCircumference)+(0.720{SBP})+(0.426{Age})

Where:ThighCircumferenceisincentimeters(cm),SBPisthesystolicblood pressureinmmHg,Ageisinyears.Duringeachtrainingsession,thecuffswill

betiedtothemostproximalendsofthesubject’slowerlimbsbasedonthe mainmusclegroupstrained,andbloodflowwillbelimitedto50%LOPofthe individual’slimbs.Atthesametime,resistancetrainingintensitywillbe20–30%1-RM.Thevolumewillfollowaschemefrom30repetitionsinthefirstset and15repetitionsinsecondandthirdsets.Therestperiodsbetweenthesets will be 30 s with the cuffs remaining inflated during rest. The blood flow restrictionlastedforatotalof6.5minutes.Then,thecuffswillbecompletely relaxedtoallowbloodreperfusion,duringwhichtimetwosets ofcoremuscle grouptrainingswillbecontinued.Therewillbearestperiodof30sbetween sets.The total time forblood flow restriction+ reperfusion training will be ten minutesforeachround,withthreeroundsin total foratotalof30minutes.Itis importanttonotethattheappliedcuffpressureshouldnotcausepainorany obviousdiscomfortinthesubjectduringtraining,andcanbeadjustedto40–50%LOPbasedonthecomfortofthesubject.Thegoalinthisstudywillbeto use pressure sufficient to induce muscle adaptation while minimizing discomforttoavoidinterruptionsinexerciseduetosubcutaneousbleeding, thrombosis,limbsoreness,andotherproblemsinthesubject.Informationon thisregimenisshowninTable1.**(Hughesetal.,2017).**

Action	Time	Training location	Main movement
Inflation and pressurization	1 minute		Intensity: 20%–30% 1-RM. 10 minutes × 3 = 30 minutes
Repetitions: 1st set: 30 → 2nd set: 15→ 3rd set: 15 → 4th set: 15	A total restriction time = 6.5 minutes	Training on both upper or lower limbs with 40–50% LOP	
Interval between sets: 30 seconds			
Complete deflation and rest	30 seconds		
Continue resistance training without blood flow restriction	2 sets + 30 seconds rest × 2 = 2 minutes	Core muscles	

LOP, limb occlusion pressure; 1-RM, one-repetition maximum.

Round 1 –

Quadriceps **ChairSquat/**

Sit-to-Stand 1st set: 30 reps

2nd&3rdsets:15 reps

Rest: 30 sec (cuffs stay inflated)

Round2–

Glutes&Hamstrings **Glute Bridge**

1stset:30reps

2nd&3rdsets:15 reps

Rest:30sec(cuffsstayinflated)

Round3–Calves&Ankles

HeelRaises(standing,holdingsupportifneeded)

1stset:30reps

2nd&3rdsets:15 reps

Rest:30sec(cuffsstayinflated)BetweenRounds

Releasecuffsfully(allowreperfusionfor~1–2minutes)

CoreExercises:(1-2minutesafterreleasecuffsineachround)

- Clamshellsinfirstround.
- Pelvicrockinginsecondround.
- Transverseabdominisactivationinthirdround.

GroupB: ControlGroup(Exercise-Only)

Participantsinthecontrolgroup willengage in amoderate intensity exerciseregimen,designedtoimprovemuscularstrength,balance, andfunctionalmobility.

SessionStructure:

A. **Warm-up(5minutes):**
    - Lightwalkingorsteppinginplace
    - Dynamicstretchestargetinglowerlimbs

B. **Resistance Exercises (30 minutes):** Resistance training will be performed using small equipment such as weights, hip and leg exercises Targeting quadriceps and associated lower limb musculature willbemainlyselected fortraining.Theinitialintensity ofthestrengthtrainingprogramwilllow(40%–50%1-RM)toreduce musclesoreness,avoidValsalvamovementsandtendoninjuries, andensureproperweightliftingform.Iftheparticipantcouldfully

adapt,thatwill,repeat10–15times/setwiththesameresistance, complete2–4sets,andself-ratethedegreeoffatigueduringand after exercise to achieve 12–13 points of the Borg ratings of perceived exertion (RPE) scale, resistance can be gradually increased 5%–10% 1-RM until they can complete the moderate-intensityresistancetrainingatapersonal60%-70%1-RM,repeating 10–15times/set,60secondsintervalbetweensets.Table2shows thedetailedresistancetrainingscheme.

Weeks	Intensity (% 1-RM)	Repetitions	Perceived Exertion (Rating on 6–20 RPE Scale)	Interval between sets	Frequency (times/ week)	Sets
1 (Pre-intervention)	40–50	8–12	9–11	1 minute	3	2–4
2 (Pre-intervention)	45–55	10–15	9–12			
1–2 (Intervention)	55–60	8–12	12–13			
3–4	55–60	10–15	12–13			
5–8	60–65	8–12	12–13			
9–12	60–65	10–15	12–14			

BalanceExercises(10minutes):

Tandemstandingandwalking

Single-legstancewithsupport

Step-tapsandmultidirectionalreaching

Cool-down(5minutes):

Lightwalking.

Staticstretchingforquadriceps,hamstrings,andcalves.

Thetherapisthastoendthesessionimmediatelyifthepatientscomplainof:

1. Suddenchestpain.
2. Fatigue.
3. Cyanosis.
4. Nauseaorvomiting.
5. Dizziness.
6. Dyspnea.
7. Hyperventilation.
8. Ifpatientsaskedtostop.

Statisticalanalysis

- AllanalysiswillbecarriedoutusingthestatisticalpackageSPSSV.25.00 (IBM Corporation).
- DatawillbeexpressedasmeanandSDormedian(incaseofviolationof normality) for continuous variables and as percentages for categorical data.
- TheShapiro-Wilkstestwillbeusedtotestthenormalityofthedata.
- 2-waymixedDesignMANOVAwillbeusedtocomparethegroupsfor normally distributed data.
- Kruskal Wallis and Mann-Whitney tests will be used to compare the groups for non-parametric and not normally distributed data.
- PairwisemultiplecomparisonswillbeperformedusingtheBonferroni correction test.
- Alltestsaretwo-sided,andstatisticalsignificancewillbesetat$p<0.05$.

REFERNCES

- Alahmari, K. A., C Reddy, R. S.(2025).Evaluation of lower-limb strength andproprioceptioninpatientswithtype2diabetesmellitus:Across-sectionalstudy.JournalofDiabetesCMetabolicDisorders,25(1),34–42.
- https://doi.org/10.1007/s40200-025-01123-8
- American Diabetes Association. (2023).Standards of medical care in diabetes—2023. Diabetes Care, 46(Suppl 1), S1–S300. https://doi.org/10.2337/dc23-S001
- American Diabetes Association. (2024).Standards of medical care in diabetes—2024. Diabetes Care, 47(Suppl 1), S1–S330. https://doi.org/10.2337/dc24-S001
- Dünnwald, T., Gatterer, H., Faulhaber, M., Arvandi, M., C Schobersberger, W.(2021).Monitoringbloodoxygenation withpulse oximetry: Insights from mountain medicine. Sensors, 21(4), 1190. https://doi.org/10.3390/s21041190
- Horsley,I.G.,Herrington,L.C.,CRolf,C.G.(2022).Reliabilityand validityoftheVALDDynaMo™hand-helddynamometerforlowerlimb strength assessment. Journal of Sports Sciences, 40(18), 2115–2122. https://doi.org/10.1080/02640414.2022.2051001
- Lin, H., Wu, Y., Zhang, W., Zhang, Y., C Li, S. (2024). Type 2 diabetes and fall risk in community-dwelling older adults: A two-year prospective cohort study. Diabetes Research and Clinical Practice, 212, 111234. https://doi.org/10.1016/j.diabres.2024.111234
- Liu,Z.,Guo,Y.,CZheng,C.(2024).Type2diabetesmellitus–related sarcopenia:Atypeofmusclelossdistinctfromsarcopeniaanddisuse muscle atrophy. Frontiers in Endocrinology, 15, 1375610. https://doi.org/10.3389/fendo.2024.1375610
- Loenneke,J.P.,Abe,T.,CThiebaud,R.S.(2020).Bloodflowrestriction training:Abasicunderstanding.JournalofScienceinSportandExercise, 2(1),17–24.https://doi.org/10.1007/s42978-019-00052-1

- Loenneke,J.P.,Buckner,S.L.,Abe,T.,CDankel,S.J.(2020).Exercise withbloodflowrestriction:Anupdatedevidence-basedapproachfor enhancedmusculardevelopment.JournalofStrengthandConditioning Research, 34(7), 2050–2057. https://doi.org/10.1519/JSC.0000000000003570
- Ma, X., Ai, Y., Lei, F., Tang, X., Li, Q., Huang, Y., C Ruan, S. (2024). Effect ofbloodflow-restrictiveresistancetrainingonmetabolicdisorderand bodycompositioninolderadultswithtype2diabetes:Arandomized controlled study. Frontiers in Endocrinology, 15, 1409267. https://doi.org/10.3389/fendo.2024.1409267
- Naruse, K., Yokokawa, H., Fukuda, H., et al. (2024). Physical performance and muscle strength in patients with type 2 diabetes mellitus:Acomparativeanalysis.ClinicalInterventionsinAging,19,11–20.https://doi.org/10.2147/CIA.S440182
- Pan, B., Sun, X., Wang, W., C Zhao, H. (2018). The effectiveness of resistance training on glycemic control in type 2 diabetes: A meta-analysis. Medicine, 97(47), e12962. https://doi.org/10.1097/MD.0000000000012962
- Patterson, S. D., Hughes, L., Warmington, S., Burr, J., Scott, B. R., Owens, J., ... C Blood Flow Restriction Consensus Group. (2022). Blood flow restrictionexercise:Considerationsofmethodology,application,and safety.FrontiersinPhysiology,13,896907. https://doi.org/10.3389/fphys.2022.896907
- Wedig, I. J., Lennox, I. M., Petushek, E. J., McDaniel, J., Durocher, J. J.,C Elmer,S.J.(2024).Developmentofapredictionequationtoestimate lower-limbarterialocclusionpressurewithathighsphygmomanometer. EuropeanJournalofAppliedPhysiology,124(6),1281–1295.
- Sasidharan,S.,Krishnakumar,M.,CBalakrishnan,V.(2025).Test–retest reliabilityofActivForce2digitaldynamometerforisometrickneeflexion and extension in healthy adults. Journal of Neonatal Surgery, 14(2),

Article 6289. https://www.jneonatalsurg.com/index.php/jns/article/view/6289

- Scott,B.R.,Loenneke,J.P.,Slattery,K.M.,CDascombe,B.J.(2022).The cellularmechanismsofbloodflowrestrictiontraining-inducedmuscle hypertrophy: A review. Sports Medicine, 52(3), 509–528. https://doi.org/10.1007/s40279-021-01575-5
- Shaw,B.S.,Shaw,I.,CKruger,P.E.(2023).Barrierstophysicalactivity inpatientswithtype2diabetesmellitus:Areview.JournalofPhysical ActivityResearch,8(1),45–51.https://doi.org/10.12691/jpar-8-1-7
- Wan, C., C Su, Y. (2024). Effects of resistance training on glycemic control and metabolic health in patients with type 2 diabetes: A systematicreviewandmeta-analysis.DiabetesCMetabolicSyndrome: ClinicalResearchCReviews,18(2),102547. https://doi.org/10.1016/j.dsx.2024.102547
- Yamada, T., Higuchi, M., Kinoshita, Y., Sato, M., C Arai, H. (2024). Functionalbalanceandlowerextremitystrengthinindividualswithtype 2 diabetes: A comparative analysis. Journal of Aging and Physical Activity,32(2),135–144.https://doi.org/10.1123/japa.2023-0198
- Yasuda, T., Fukumura, K., Iida, H., C Nakajima, T. (2020). Effectsof low-load resistance training with and without blood flow restriction on muscle strength and functional capacity in older adults with T2DM. Clinical Interventions in Aging, 15, 1491–1499. https://doi.org/10.2147/CIA.S264228
- Zhao,R.,Liu,L.,Zhang,D.,Wu,Q.,CChen,Y.(2024).Type2diabetes mellitusandtheriskoffallsinolderadults:Asystematicreviewand meta-analysis.JournalofGerontology:MedicalSciences,79(1),45–53. https://doi.org/10.1093/gerona/glad210
- Zhu,S.,Shen,Y.,Wang,H.,CChen,L.(2021).Prevalenceofsarcopenia inpatientswithtype2diabetes:Ameta-analysis.JournalofDiabetes Investigation,12(3),464–472.https://doi.org/10.1111/jdi.13355

APPENDIXI

I am..... Freely and voluntarily, consent to participate in this research studyunder the direction of the researcher /KHALID ABDELHAKEM ELSAYED ALI

AthoroughdescriptionoftheprocedureshasbeenexplainedandIunderstandthatImaywithdraw my consent and discontinue participation this research at any time without prejudice to me.

Date:/ /

2025Participant/.....

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