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RS Global Sp. z O.O.
ISNI: 0000 0004 8495 2390

Dolna 17, Warsaw,
Poland 00-773
+48 226 0 227 03
editorial_office@rsglobal.pl

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THE ROLE OF SQUAT EXERCISE IN MEDICAL PRACTICE:
EVIDENCE AND CLINICAL APPLICATIONS

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THE ROLE OF SQUAT EXERCISE IN MEDICAL PRACTICE: EVIDENCE AND CLINICAL APPLICATIONS

Michał Wabiszczewicz (Corresponding Author, Email: michalwabi@gmail.com)
Medunit Primary Care Clinic, Marii Skłodowskiej-Curie 5, 80-210 Gdańsk, Poland
ORCID ID: 0009-0006-0339-5628

Albert Lompart
Saint Wojciech Hospital (Copernicus Hospital), al. Jana Pawła II 50, 80-462 Gdańsk, Poland
ORCID ID: 0009-0006-7591-4765

Albert Kosarewicz
University Clinical Centre of Gdańsk Medical University, Dębinki 7, 80-952 Gdańsk, Poland
ORCID ID: 0009-0004-9108-1754

Łukasz Woźniak
West Pomeranian Center for the Treatment of Severe Burns and Plastic Surgery, ul. Niechorska 27, Gryfice, Poland
ORCID ID: 0009-0009-6452-3066

Patrycja Krysiak
Medical University of Łódź, al. Tadeusza Kościuszki 4, 90-419 Łódź, Poland
ORCID ID: 0009-0006-5777-3751

ABSTRACT

Introduction and Objective: The squat is a fundamental human movement and widely used exercise with recognized importance in sports, rehabilitation, and preventive medicine. This narrative review aims to summarize current evidence (2020–2025) on the medical impact of squat exercise across diverse populations, emphasizing musculoskeletal, skeletal, cardiovascular, and functional outcomes.

Review Methods: A structured search was conducted in PubMed, PLOS One, Wiley, and JSTOR for articles published between January 2020 and February 2025. Inclusion criteria were peer-reviewed human studies addressing health-related effects of squat exercises. Exclusion criteria included animal studies, conference abstracts, and articles focusing solely on athletic performance. Approximately 30 key studies were analyzed narratively.

State of Knowledge: Evidence indicates that squat training improves muscle strength, hypertrophy, and bone mineral density, with quadriceps showing the largest force gains (~18%). Cardiovascular and metabolic adaptations include improved oxygen consumption, blood pressure regulation, and postprandial glucose control. Functional benefits extend to older adults, where squats enhance sit-to-stand capacity and daily mobility, and to special populations such as pregnant women, where squats reduce fatigue and improve quality of life. Variations in depth, load, and technique influence outcomes and safety.

Summary: Squat exercise represents a versatile intervention with significant health benefits across age groups and clinical conditions. Incorporating squats into individualized exercise prescriptions may help prevent osteoporosis, sarcopenia, cardiovascular disease, and functional decline, reinforcing its role in evidence-based medical and rehabilitation practice.

KEYWORDS

Exercise, Squat, Resistance Training, Musculoskeletal Health, Rehabilitation

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1. Introduction

Background and Significance

The squat is a fundamental movement pattern used in daily life and athletic performance. As a compound exercise, it engages multiple muscle groups and induces musculoskeletal and cardiovascular adaptations. Beyond traditional strength gains, squats are increasingly recognized for their broader health benefits, relevant in preventive medicine, rehabilitation, and geriatrics. Their biomechanical similarity to everyday tasks supports functional independence, while incorrect technique may increase injury risk.

Aims and Objectives

This narrative review examines the medical impact of squat exercise, with emphasis on musculoskeletal strength, bone health, cardiovascular and metabolic adaptations, functional outcomes, and safety considerations.

Scope of Review

The review covers research from 2020 to 2025, including different squat modalities (e.g., back, front, bodyweight) and varying training approaches. Both acute effects and long-term adaptations are considered to provide a comprehensive yet practical overview.

2. Research Materials and Methods

Search Strategy and Sources

A literature search was conducted in PubMed, PLOS One, Wiley, JSTOR, and Google Scholar for publications from January 2020 to February 2025. Search terms included "squat" OR "squatting" combined with "health," "bone density," "muscle strength," "cardiovascular," "rehabilitation," or "functional performance."

Inclusion and Exclusion Criteria

We included peer-reviewed studies in English that examined health-related outcomes of squat exercises across different populations. Studies limited to athletic performance, non-human experiments, and conference abstracts were excluded.

Synthesis of Evidence

Given the diversity of study designs and outcomes, findings were summarized narratively rather than through meta-analysis. Studies were grouped by primary outcome domains (musculoskeletal, skeletal, cardiovascular, and functional health) to provide a structured overview of current knowledge.

3. Basic Results

3.1 Musculoskeletal Adaptations

Squats are highly effective for improving muscle strength and hypertrophy. Regular training can increase maximal force by ~18.8% and rate of force development by ~37% within 8 weeks, mainly in the quadriceps (Ribeiro et al. 2023). Hypertrophy is region-specific: quadriceps show marked growth, while hamstrings benefit less, suggesting complementary exercises are needed. Squat depth affects outcomes: full squats enhance neuromuscular adaptations and BMD (Zhang et al. 2021; Laver 2021; Ribeiro et al. 2020). Gluteus maximus also adapts more with deeper squats, though longitudinal data remain limited (Ribeiro et al. 2023).

Squats also improve bone health, particularly lumbar spine and femoral neck density (Zhang et al. 2021; Harding et al. 2020). Benefits vary by age: adolescents show reduced body fat and higher BMD (Ribeiro et al. 2023), while older adults improve lower limb function regardless of squat depth (Yoshiko & Watanabe 2021; Trybulski et al. 2023). Consistency and training volume appear more important than depth.

Table 1 summarizes the main musculoskeletal adaptations to squat training reported in recent studies, including changes in muscle strength, rate of force development, and bone mineral density.

Table 1. Musculoskeletal Effects of Squat Training (Selected Studies 2020–2025)

Author (Year)	Population	Intervention	Main Findings
Ribeiro et al. (2023)	Adults, 8-week training	Squat, varying depth	↑ Maximal strength by ~18.8%; ↑ Rate of force development by ~37%; strongest adaptations in quadriceps
Zhang et al. (2021)	Osteopenia/osteoporosis patients	Full squat, resistance training	↑ Bone mineral density (BMD) in lumbar spine and femoral neck
Yoshiko & Watanabe (2021)	Older adults	Home-based squats at two depths	Improved lower limb function regardless of squat depth
Harding et al. (2020)	Men 50+ with low bone mass	Squat + high-intensity resistance training	↑ BMD and leg function

3.2 Cardiovascular and Metabolic Effects

Acute responses include increased heart rate, blood pressure, and cardiac output, influenced by squat depth, load, and fitness level (Wilk et al. 2021; Chukwuemeka et al. 2024; Jarosz et al. 2023). Peripheral vasodilation and central adaptations (higher stroke volume and oxygen delivery) underlie these effects (Rojas-Jaramillo et al. 2024).

Chronic adaptations include reduced resting heart rate and blood pressure, reflecting improved efficiency (Raichlen et al. 2020). Squat training at moderate-to-high intensity 2–3 times per week is optimal (Trybulski et al. 2022; Laver 2021). Benefits extend to rehabilitation, where supervised squats aid cardiovascular conditioning in patients with comorbidities (Chukwuemeka et al. 2024).

Metabolically, squats elevate post-exercise oxygen consumption by ~59% (Ribeiro et al. 2020, 2023), supporting fat loss and energy balance. Training enhances insulin sensitivity, glucose control, and lipid profiles (Raichlen et al. 2020). Full-depth squats recruit more muscle mass, increasing caloric expenditure (Trybulski et al. 2022). Integrating squats into HIIT further reduces visceral adiposity and improves metabolic flexibility. Benefits extend to older adults and those with metabolic disorders when progression is gradual (Laver 2021).

To provide a clearer overview, Table 2 presents the key cardiovascular and metabolic outcomes associated with squat training, along with representative sources.

Table 2. Cardiovascular and Metabolic Effects of Squats

Parameter	Change / Result	Source
Resting heart rate	↓ after training	Raichlen et al. (2020)
Blood pressure	↓ after training	Raichlen et al. (2020)
Oxygen consumption (VO ₂)	↑ delivery and efficiency	Rojas-Jaramillo et al. (2024)
Excess post-exercise O ₂ consumption (EPOC)	↑ by ~59%	Ribeiro et al. (2020, 2023)
Postprandial glucose	↓ improved control	Raichlen et al. (2020)
Lipid profile	Improved	Raichlen et al. (2020)
Training frequency (2–3 sessions/week)	Optimal CV and metabolic adaptations	Trybulski et al. (2022); Laver (2021)

3.3 Functional and Rehabilitation Applications

Squats improve functional performance such as sit-to-stand, stair climbing, and mobility, especially in older adults (Yoshiko & Watanabe 2021). In pregnancy, they reduce fatigue, support posture, and improve quality of life (Malmir et al. 2022). Mechanisms include stronger quadriceps and gluteals, enhanced neuromuscular coordination, and improved pelvic stability (Song et al. 2023; Straub & Powers 2024).

In rehabilitation, squats are widely used for PFP, chronic low back pain, and ACL injury. Modifications in stance, trunk position, and tibia angle help tailor joint loading (Straub & Powers 2024; Luna et al. 2021). Squats are safer than open-chain exercises in ACL rehab, promoting gradual dynamic stability.

3.4 Biomechanical Considerations and Prescription

Squat depth and stance width strongly influence joint kinematics and muscle recruitment (Larsen et al. 2021; Song et al. 2023; Straub & Powers 2024). Deeper squats increase knee/hip moments but remain safe when performed correctly; only limited evidence links them to injury (Rojas-Jaramillo et al. 2024). Foot and ankle mobility also play a role in knee mechanics and injury risk (Zawadka et al. 2021). AI-based tools show promise for technique assessment, though specificity remains low (Luna et al. 2021).

Proper technique—neutral spine, knee alignment, balanced weight distribution—is essential for safety (Larsen et al. 2021). Older adults should use gradual progression, from supported to free squats (Yoshiko & Watanabe 2021).

Programming evidence suggests 2–3 sessions per week, 3–5 sets of 6–12 reps, with progressive overload as key (Ribeiro et al. 2023; Harding et al. 2020). Strength goals benefit from 70–85% 1RM, while hypertrophy adapts better at 50–70% 1RM. Periodisation strategies, both linear and undulating, prevent plateaus and support long-term adaptation (Kong et al. 2023). Traditional squatting postures, such as those in non-industrial societies, highlight its role in naturalistic movement and sedentary time mitigation (Raichlen et al. 2020).

4. Conclusions

4.1 Summary of Key Findings

Squats effectively improve musculoskeletal and metabolic health. Regular training increases maximal strength (~18.8%) and rate of force development (~37% in 8 weeks), with strongest adaptations in the quadriceps (Ribeiro et al., 2023). Bone health benefits are supported by systematic reviews showing significant improvements in BMD, especially at the lumbar spine (Zhang et al., 2021). Cardiovascular adaptations include reduced resting heart rate and blood pressure, together with substantial post-exercise oxygen consumption (~59%) (Raichlen et al., 2020; Ribeiro et al., 2023). Functionally, squat training enhances mobility and sit-to-stand capacity in older adults within weeks (Yoshiko & Watanabe, 2021). Despite concerns, deep squats are safe when performed correctly (Rojas-Jaramillo et al., 2024).

4.2 Clinical Implications and Recommendations

Exercise prescription should be individualized, adjusting stance width, foot rotation, trunk angle, tibia position, and squat depth to therapeutic goals (Straub & Powers, 2024).

- Bone health: Moderate-to-high intensity with progressive loading is most effective. Combined approaches (resistance, aerobic, mind–body) are beneficial, with some evidence for superior site-specific results of mind–body training (Cui et al., 2023; Zhang et al., 2021).
- Cardiovascular health: Intensity and volume must be matched to individual condition; medical clearance and monitoring are essential for patients (Trybulski et al., 2022; Laver, 2021; Chukwuemeka et al., 2024).
- Pregnancy: Appropriately prescribed squats reduce fatigue and improve quality of life, especially in late pregnancy (Malmir et al., 2022).
- Older adults: Consistency and proper technique are more important than depth or load. Both shallow and deep squats improve function if performed regularly (Yoshiko & Watanabe, 2021).

Patient education (technique, expected outcomes, misconceptions) and interdisciplinary collaboration (therapists, physicians, physiologists, nutritionists) improve adherence and outcomes (Straub & Powers, 2024).

4.3 Research Limitations and Future Directions

Current research is heterogeneous in squat protocols, populations, and outcome measures, limiting comparability. Standardization of definitions and assessments would enable more robust comparisons and meta-analyses. Long-term studies (>12 weeks) are scarce; sustained effects, optimal progression, and

periodization require investigation. Mechanistic pathways remain partly unclear—molecular, imaging, and computational studies may improve understanding. Population-specific trials (osteoporosis, patellofemoral pain, cardiovascular disease) would refine clinical applications (Trybulski et al., 2022; Raichlen et al., 2020; Zhang et al., 2021).

4.4 Concluding Remarks

Evidence strongly supports squats as a versatile, low-cost, and effective intervention to enhance musculoskeletal, cardiovascular, and functional health across populations. Their adaptability to individual goals and limitations makes them a cornerstone exercise in prevention, rehabilitation, and health promotion. With future refinement of programming and execution parameters, squat training will continue to provide substantial health benefits throughout the lifespan (Ribeiro et al., 2023; Kong et al., 2023; Laver, 2021).

Disclosure

Author's contribution:

Conceptualization; Michał Wabiszczewicz, Łukasz Woźniak
methodology; Albert Kosarewicz, Łukasz Woźniak
software; Patrycja Krysiak, Michał Wabiszczewicz, ;
check; Albert Lompart, Albert Kosarewicz
formal analysis; Albert Lompart
investigation; Michał Wabiszczewicz, Patrycja Krysiak
resources; Albert Kosarewicz, Łukasz Woźniak, Patrycja Krysiak
data curation; Patrycja Krysiak
writing - review and editing; Michał Wabiszczewicz, Albert Lompart, Łukasz Woźniak
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