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ORIGINAL ARTICLE

Biochemical Analysis of Age-Related Hormonal Changes and Their Impact on Metabolic Pathways - A Cross-Sectional Study

SYED NAVEED HAIDER[1], NAVEED SHUJA[2], RAZIA BATOOL[3], QURATULAAIN ZOHRA[4], AQEELA KOUSAR[5], M. AKEEL[6]
[1]Senior Medical Officer, District Health Authority Narowal, Pakistan
[2]Associate Professor Biochemistry Department, Lahore Medical & Dental College Lahore, Pakistan.
[3]Lecturer/ Lab Incharge in Forensic Medicine Department Sahara Medical College, Narowal, Pakistan.
[4]Senior Lecturer Biotechnology, The Sahara College Narowal, Pakistan.
[5]Lecturer/Lab Technologist in Pathology Department Sahara Medical College, Narowal, Pakistan.
[6]Air Medical Officer Punjab Emergency Department, Pakistan
Correspondence to: Dr. Naveed Shuja, **Email:** rananaveedshuja@gmail.com, **Cell:** 0333-4205687

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ABSTRACT

Background: Gradual changes in hormonal levels with aging are associated with severe changes in biochemical pathways controlling metabolic, protein synthesis, and energy balance. A basic understanding of these age related hormonal changes is necessary to early detection of metabolic disorders and age specific therapeutic intervention.
Aim: Biochemically evaluate the relationship between metabolic pathway disturbances due to age-related hormonal changes in a population of 100 individuals from different age groups.
Methodology: This was a descriptive, cross sectional study done from July to December 2024 at the Department of Biochemistry, Lahore Medical & Dental College Lahore. A total of 100 patients were enrolled and divided into three age groups: young adults (20–35 years), middle aged adults (36–60 years) and elderly patients (>60 years) in an equal proportion. Levels of insulin, cortisol, thyroid hormones (T3, T4, and TSH), testosterone (males), estrogen (females), IGF-1 and growth hormone were analyzed from fasting venous blood samples.
Results: The elderly group showed significant decline in IGF-1 ($p<0.001$), testosterone ($p<0.01$), estrogen ($p<0.05$) and growth hormone ($p<0.001$) compared to younger subjects. With increasing age ($p< 0.05$), the levels of cortisol and TSH increased slightly, but statistically, these levels were slightly increased. There were corresponding changes in metabolic markers including elevated fasting glucose and total cholesterol in the elderly group ($p<0.01$). IGF-1 and HDL levels showed positive correlation and cortisol and insulin sensitivity markers showed negative correlation.
Conclusion: Hormonal shifts associated with age have a significant impact on metabolism. Older individuals may be predisposed to insulin resistance, dyslipidemia and altered liver and renal biochemistry as a result of declining anabolic hormones, increased catabolic hormone levels.
Keywords: Anabolic Hormones, Catabolic Hormone levels, Cortisol, specific therapeutic intervention

INTRODUCTION

Aging is a long, complex, multifactorial process in which there are progressive physiological, biochemical and molecular alterations that cumulatively affect homeostatic mechanisms in several organ systems[2]. Of these, endocrine function has a particularly profound shift with age and impacts regulation of growth, metabolism, tissue repair, and cellular signaling. It is becoming increasingly clear that hormonal dysregulation is a central hallmark of aging and intersects with metabolic syndromes, sarcopenia, cognitive decline, and cardiovascular decline[5].

While the endocrine system is controlled via tightly regulated feedback mechanisms, age dependent changes such as decreased GH and IGF-1 secretion, sex steroid deficiencies, altered adrenal and thyroid hormone output have been associated with metabolic dysregulation[3]. Decreases in anabolic hormones (testosterone, estrogen, IGF-1) decrease protein synthesis, lean muscle mass; elevations in catabolic hormones (cortisol) worsen insulin resistance, central adiposity and systemic inflammation[2]. In addition, thyroid dysfunction is more common with age and results in fluctuations of basal metabolic rate and energy imbalance[6].

While the wide consensus on the hormonal alterations with aging, we lack region-specific biochemical evidence of these changes in a structured structure population based setting[10]. Previous studies have primarily considered hormone measurements in isolation or in limited demographic scope without accounting for metabolic changes[9]. Additionally, the interrelationship between hormone fluctuations and hepatic, renal and lipid biochemistry in elderly individuals is not yet fully understood[8].

In order to bridge this gap, this study aims to perform a comprehensive biochemical analysis of key hormonal parameters and their metabolic correlates in different age groups within a single clinical framework[7]. We stratify a representative cohort of 100 individuals into young, middle aged and elderly brackets in order to delineate age related trends of endocrine function and downstream effects on metabolic pathways[19]. These findings are expected to provide novel insights into endocrine aging and their implications for designing age appropriate interventions for metabolic health preservation.

MATERIAL AND METHODS

Study Design

A descriptive, cross sectional study was carried out in the Department of Biochemistry, LM&DC Ghurki Hospital, a tertiary care academic medical facility in Lahore, Pakistan from July to December 2024. The Institutional Ethical Review Committee had reviewed and approved the study protocol and all participants gave written informed consent prior to enrollment.

Study Population

Total enrolled 100 participants purposively. Apparently healthy adults 20 years of age or above without endocrine disorders or metabolic disease or taking any hormonal replacement or lipid lowering therapy were included in the inclusion criteria. There were 33–34 participants in each age group (Group A, 20–35 years; Group B, 36–60 years; Group C, >60 years). Individuals with a history of chronic liver disease, renal insufficiency, malignancy, diabetes mellitus, or thyroid dysfunction and recent (within 3 months) corticosteroid therapy were excluded.

Sample Collection

10 mL of venous blood was collected overnight fasted (8–10 hours), between 7:00 and 9:00 AM to control for diurnal variations of hormonal levels. Serum was separated from blood samples centrifuged at 3000 rpm for 10 min at 4°C, aliquoted, and stored at −80°C until further biochemical and hormonal analysis.

Hormonal and Biochemical Assays

The serum levels of insulin, cortisol, growth hormone (GH), insulin like growth factor-1 (IGF-1), thyroid stimulating hormone (TSH), triiodothyronine (T3), thyroxine (T4), testosterone (males), and estrogen (females) were measured quantitatively by ELISA kits (DRG Instruments GmbH, Germany; Bioassay Technology Laboratory, China) using manufacturer protocols. Intra assay coefficients of variation were less than 10% for all samples and analyzed in duplicate.Routine biochemical parameters such as fasting blood glucose (FBG), lipid profile (Total cholesterol, HDL, LDL, triglycerides), serum creatinine, blood urea nitrogen (BUN), alanine transaminase (ALT) and aspartate transaminase (AST) were analyzed using automated chemistry analyzers with internal quality control (QC).

Statistical Analysis:

IBM SPSS version 26.0 (IBM Corp, Armonk, NY, USA) was used to analyze data. Data were presented as continuous variables as mean ± standard deviation (SD) or median with interquartile range (IQR) as appropriate. To compare the hormone and biochemical levels between the three age groups, one way analysis of variance (ANOVA) with post hoc Tukey's test was performed. Associations between hormone levels and metabolic markers were evaluated using Pearson's correlation coefficient. Statistically significant was declared a p-value < 0.05.

RESULTS

A comparative analysis of key hormonal markers in three defined age groups: young adults (20 to 35 years), middle aged adults (36 to 60 years) and elderly individuals (>60 years) is presented in Table 1. As the age progresses, anabolic hormones such as IGF-1, growth hormone, testosterone (in males), and estrogen (in females) show a clear declining trend. For example IGF-1 levels are very low in the elderly at 135 ± 22 ng/mL compared to young adults at 210 ± 34 ng/mL with a very low p-value (<0.001).

Likewise, growth hormone levels were reduced in a marked way with increasing age ($p<0.001$). Age was associated with decreased levels of testosterone and estrogen, indicating decreased gonadal activity, and this may in part explain age associated physiological changes like sarcopenia, fatigue, and decreased libido. For example, on the one hand, catabolic hormones such as cortisol and regulatory hormones such as TSH showed a statistically significant increase with age ($p<0.05$), indicating that the elderly have increased stress response and thyroid compensatory mechanisms (Table 2).

Table 2 highlights the metabolic implications of hormonal changes through an evaluation of key biochemical parameters. Glucose levels increased progressively with age across the age groups with 104 ± 18 mg/dL in the elderly indicating declining insulin sensitivity and a potential risk for glucose intolerance or type 2 diabetes ($p<0.01$). In addition, total cholesterol and LDL levels were significantly increased with age ($p<0.01$), but protective HDL cholesterol decreased significantly ($p<0.05$) in older individuals, indicating an increased cardiovascular risk profile. In addition, elderly patients also had elevated hepatic enzyme ALT and serum creatinine levels ($p < 0.05$), markers of liver and kidney functions, respectively. The observed hormonal changes and these metabolic shifts together support the hypothesis that aging results in disruption of homeostasis by disrupting endocrine regulation and biochemical stability and predisposing older individuals to metabolic syndromes and organ function decline.

Table 1: Comparison of Hormonal Parameters across Age Groups (Mean ± SD)

Hormonal Parameter	20–35 Years	36–60 Years	>60 Years	p-value
IGF-1 (ng/mL)	210 ± 34	172 ± 28	135 ± 22	<0.001
Growth Hormone (ng/mL)	4.2 ± 1.1	3.1 ± 0.9	2.0 ± 0.6	<0.001
Testosterone (ng/dL)*	540 ± 80	420 ± 70	310 ± 65	<0.01
Estrogen (pg/mL)**	120 ± 18	98 ± 14	78 ± 12	<0.05
Cortisol (µg/dL)	13.4 ± 2.3	15.6 ± 2.7	17.2 ± 3.0	<0.05
TSH (µIU/mL)	1.8 ± 0.6	2.4 ± 0.7	3.0 ± 0.9	<0.05

*Testosterone: reported in males only
**Estrogen: reported in females only

Table 2: Comparison of Metabolic and Biochemical Parameters across Age Groups (Mean ± SD)

Biochemical Parameter	20–35 Years	36–60 Years	>60 Years	p-value
Fasting Glucose (mg/dL)	85 ± 12	96 ± 15	104 ± 18	<0.01
Total Cholesterol (mg/dL)	168 ± 22	190 ± 25	212 ± 30	<0.01
HDL (mg/dL)	55 ± 9	49 ± 8	44 ± 7	<0.05
LDL (mg/dL)	95 ± 15	108 ± 18	120 ± 20	<0.01
ALT (U/L)	24 ± 6	28 ± 7	33 ± 9	<0.05
Creatinine (mg/dL)	0.8 ± 0.1	0.9 ± 0.2	1.1 ± 0.3	<0.01

DISCUSSION

In the present study, the complexity of the association between age's related hormonal changes and metabolic changes was investigated in a cohort of 100 participants in the three different age groups. We find compelling evidence that aging is associated with a large decrease in anabolic and key hormones including IGF-1, growth hormone, testosterone and estrogen, and an increase in catabolic and regulatory hormones such as cortisol and TSH[11]. These hormonal variations were very well correlated with unfavorable changes in metabolic parameters and thus support the hypothesis that endocrine aging is a key factor in metabolic dysregulation[12].

The observed reduction in IGF-1 and growth hormone levels is consistent with well described 'somatopause' phenomenon of declining growth hormone secretion with increasing age. However, this decline contributes to a decreased lean muscle mass, decreased protein synthesis, and impaired tissue repair[14]. Similarly, reductions in gonadal sex steroids such as testosterone and estrogen, which are consistent with gonadal atrophy with age, have been shown in previous literature to correlate with sarcopenia, osteoporosis, and metabolicsyndrome. In our study population, this is particularly true for estrogen deficiency in postmenopausal women, as it has been associated with central adiposity and lipid abnormalities[13].

The small increase in cortisol level in older adults has clinical importance. Chronic elevation of cortisol has been shown to induce insulin resistance, visceral obesity and immunosuppression. We also found that TSH increases

progressively with age[17]. This study adds to the existing literature about how differentially aging affects males and females by providing gender specific hormonal trends in this study[15]. This decline of testosterone was more pronounced and significantly associated with dyslipidemia and elevated fasting glucose levels indicating the role of androgens in preserving insulin sensitivity and lipids balance in males. The cardio- protective role of estrogen in premenopausal women was supported by the finding that in females, reduced estrogen levels post menopause were associated with elevated LDL and reduced HDL levels[16].

These distinctions highlight the necessity of sex-specific diagnostic thresholds and therapeutic approaches to age related changes in hormonal and metabolic state[18]. Hormonal assessments integrated into routine geriatric evaluations (especially in high risk populations of metabolic syndrome, such as postmenopausal women and elderly men) may allow earlier identification of individuals at risk for metabolic disorders and lead to more targeted lifestyle or pharmacological interventions to delay or prevent progression of metabolic disorders[19].

CONCLUSION

Hormonal shifts associated with age have a significant impact on metabolism. Older individuals may be predisposed to insulin resistance, dyslipidemia and altered liver and renal biochemistry as a result of declining anabolic hormones, increased catabolic hormone levels. These findings highlight the need for routine hormonal and metabolic screening in aging populations to facilitate early intervention and health optimization.

DECLARATION

Acknowledgement:
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Authors contribution
Each author of this article fulfilled following Criteria of Authorship:

1. Conception and design of or acquisition of data or analysis and interpretation of data.
2. Drafting the manuscript or revising it critically for important intellectual content.
3. Final approval of the version for publication.

All authors agree to be responsible for all aspects of their research work.

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Ethical Considerations:
Institutional Review Boards (IRBs) gave ethical clearance. All participants gave informed verbal and written consent. Through the course of the study, confidentiality and anonymity of patient data were strictly maintained.

Competing interests:
The authors declare that the research was conducted in the absence of any commercial or fnancial relationships that could be construed as a potential confict of interest.

Conflict of interest:
The authors declared no conflict of interest.

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