WJERT. 2026. Vol. 12 Issue 3. 80-93. **Original Article** **ISSN 2454-695X**

World Journal of Engineering Research and Technology

www.wjert.org

Impact Factor: 7.029 **Coden USA: WJERA4**

ANALYSIS AND PREDICTION OF COMPRESSIVE AND SPLIT TENSILE STRENGTH OF STEEL-FIBRE REINFORCED CONCRETE

Umana Oto-Obong I.*, Akpan Imaculata S.

Department of Civil Engineering Technology, Akwa Ibom State Polytechnic, Ikot Osurua, Ikot Ekpene, Nigeria.

Article Received on 29/01/2026 **Article Revised on 19/02/2026** **Article Published on 01/03/2026**

***Corresponding Author**

Umana Oto-Obong I.

Department of Civil Engineering Technology, Akwa Ibom State Polytechnic, Ikot Osurua, Ikot Ekpene, Nigeria.

https://doi.org/10.5281/zenodo.18812818

How to cite this Article: Umana Oto-Obong I.*, Akpan Imaculata S. (2026). Analysis and Prediction of Compressive and Split Tensile Strength Of Steel-Fibre Reinforced Concrete. World Journal of Engineering Research and Technology, 12(3), 80–93.

ABSTRACT

Steel fibres have been increasingly incorporated into concrete mixes to improve its mechanical properties and durability. This study investigates the compressive and tensile strength performance of steel fibre reinforced concrete (SFRC) at varying fibre dosages and curing ages of 7, 14, 21, and 28 days. Concrete mixes were designed with standard proportions, and steel fibres were introduced in controlled percentages. During specimen preparation, mould releasing agents were applied to ensure easy demoulding and preservation of surface integrity. Comprehensive testing was conducted on fresh and hardened concrete, including compressive strength, splitting tensile strength, regression modelling, and durability indicators. Regression analysis was applied to establish a power-type relationship between compressive and splitting tensile strength, and statistical parameters such as RMSE and MAE were used to validate accuracy. The results revealed that the inclusion of steel fibres significantly enhanced tensile strength and moderately improved compressive strength. Optimum performance was recorded at specific fibre dosages, beyond which strength gains plateaued or slightly declined. The regression model provided a reliable tool for predicting tensile behaviour from compressive results. The study concludes that steel fibre addition contributes positively to concrete's mechanical properties, particularly in tensile behaviour, making SFRC a promising material for structural applications requiring enhanced toughness and crack resistance.

KEYWORDS: Steel fibre reinforced concrete, compressive strength, tensile strength, fibre dosage, curing age, regression analysis, durability.

1. INTRODUCTION

Concrete remains the most widely used construction material worldwide due to its versatility, strength, and cost-effectiveness. However, its brittle nature and poor tensile strength limit its performance in structural applications where ductility and crack resistance are critical. To address these limitations, fibre reinforcement has emerged as a practical solution, with steel fibres proving especially effective due to their high tensile strength and ability to bridge cracks.

Previous studies have reported significant improvements in tensile behaviour and post-cracking performance with the incorporation of steel fibres. While compressive strength enhancements have been more modest, the overall structural performance of concrete with fibres demonstrates greater ductility, energy absorption capacity, and durability under service loads. Despite this, there remains variability in reported results due to differences in fibre geometry, dosage, and mix design.

This research investigates the influence of steel fibre addition on the compressive and tensile strength properties of concrete produced under controlled laboratory conditions. The objectives of the study are:

i. To determine the effect of varying steel fibre content on compressive strength at 7, 14, 21, and 28 days of curing.
ii. To assess the impact of steel fibres on tensile strength performance across the same curing ages.
iii. To identify the optimum fibre dosage for balanced improvements in compressive and tensile behaviour.
iv. To establish a regression model relating compressive and tensile strength, validated with statistical error analysis.

By addressing these objectives, the study aims to contribute to the ongoing discourse on the effective utilization of steel fibres in structural concrete. The findings are expected to guide engineers and researchers in optimizing fibre dosage for improved mechanical performance and long-term serviceability of reinforced concrete structures.

2. MATERIALS AND METHODS

2.1 Materials

Ordinary Portland Cement (OPC) conforming to standard specifications was used throughout this study. Fine aggregates were obtained from natural river sand, while coarse aggregates consisted of crushed granite with a maximum size of 20 mm. Potable water free from impurities was used in the mix preparation. Steel fibres of specific geometry and aspect ratio were introduced at varying dosages to study their effect on concrete performance.

Table 2.1: Properties of steel fibre.

Type of Fibre (N/mm^2)	Length (mm)	Diameter (mm)	Aspect Ratio ($^L/_D$)	Tensile Strength
Straight	40	0.8	50	400

Source: Computed by the researcher from the laboratory results (2025)

2.2 Mix Proportions

Concrete mixes were prepared using a controlled water-to-cement ratio and standardized mix proportions. Steel fibres were added at incremental percentages by volume of concrete. Trial mixes were carried out to ensure uniform fibre dispersion and workability.

Table 2.2: Mix Proportion of the concrete mixtures for one cubic metre.

Type of Mixture	Cement (kg)	Water (L)	Fine Aggregate (kg)	Coarse Aggregate (kg)	W/C	Fibre (kg)
PC	554.4	250	577.5	1293.6	0.45	0
SFRC 0.5	554.4	250	577.5	1293.6	0.45	12.8
SFRC 1.0	554.4	250	577.5	1293.6	0.45	25.6
SFRC 1.5	554.4	250	577.5	1293.6	0.45	38.4
SFRC 2.0	554.4	250	577.5	1293.6	0.45	51.2

Source: Computed by the researcher from the laboratory results (2025)

2.3 Specimen Preparation and Curing

Standard cube and cylinder specimens were cast for compressive and tensile strength tests, respectively. Prior to casting, moulds were treated with mould releasing agents. This practice ensured easy removal of hardened specimens, reduced the risk of surface damage, and preserved specimen geometry for accurate testing. After 24 hours of casting, specimens were demoulded and cured in water at controlled laboratory conditions until the testing ages of 7, 14, 21, and 28 days.

2.4 Testing Procedures

Workability of fresh concrete was determined using the slump test.

Compressive strength tests were carried out on cube specimens using a compression testing machine.

Splitting tensile strength tests were performed on cylindrical specimens in accordance with standard codes of practice.

2.5 Regression Modelling and Error Analysis

A regression analysis application was used to establish a mathematical relationship between compressive strength (f_c) and splitting tensile strength (f_t). A power-type model was selected due to its suitability for concrete strength relationships. The best-fit equation obtained was:

$$f_t = \underline{0.026} fc^{1.29}$$

Where f_t is splitting tensile strength (MPa) and f_c is compressive strength (MPa). To evaluate the predictive performance of the model, error analysis was conducted using Root Mean Square Error (RMSE) and Mean Absolute Error (MAE). These statistical parameters quantified the accuracy and reliability of the regression model by comparing predicted and experimental results.

3. RESULTS AND DISCUSSION

3.1 Workability of Fresh Concrete

The introduction of steel fibres reduced workability due to interlocking and balling effects. The slump values decreased progressively with fibre content, indicating reduced flowability.

3.2 Compressive Strength

Compressive strength results across different fibre dosages and curing ages are presented below.

Table 3.1: Compressive strength of cubes for 7 days.

Cube description	Sample No	Ultimate load (KN)	Compressive strength (N/mm^2)	Average compressive strength (N/mm^2)
	1	378.0	16.8	
PC	2	438.8	19.5	18.2
	3	409.5	18.2	
	1	483.5	21.5	
SFRC @ 0.5%	2	492.3	21.9	21.6
	3	478.6	21.3	

	1	589.5	26.2	
SFRC @ 1.0%	2	616.1	27.4	26.8
	3	601.9	26.8	
	1	580.3	25.8	
SFRC @ 1.5%	2	600.4	26.7	26.3
	3	595.1	26.4	
	1	677.8	30.1	
SFRC @ 2.0%	2	693.9	30.8	30.5
	3	689.4	30.6	

Source: Computed by the researcher from the laboratory results (2025)

Table 3.2: Compressive Strength of Cube cured for 14 days.

Cube description	Sample Number	Ultimate load (KN)	Compressive strength (N/mm^2)	Average compressive strength (N/mm^2)
	1	490.5	21.8	
PC	2	533.3	23.7	23.1
	3	537.8	23.9	
	1	583.2	25.9	
SFRC @ 0.5%	2	542.3	24.1	25.4
	3	587.3	26.1	
	1	677.3	30.1	
SFRC @ 1.0%	2	659.2	29.3	29.9
	3	679.5	30.2	
	1	693.0	30.8	
SFRC @ 1.5%	2	679.5	30.2	30.6
	3	69.3	30.9	
	1	762.8	33.9	
SFRC @ 2.0%	2	774.0	34.4	34.3
	3	780.8	34.7	

Source: Computed by the researcher from the laboratory results (2025)

Table 3.3: Compressive strength test of cubes cured for 21 days.

Cube description	Sample Number	Ultimate load (KN)	Compressive strength (N/mm^2)	Average compressive strength (N/mm^2)
	1	531.4	23.6	
PC	2	535.7	23.8	24.0
	3	556.3	34.7	
	1	603.5	26.8	
SFRC @ 0.5%	2	582.6	25.9	26.4
	3	596.1	26.5	
	1	734.1	32.6	
SFRC @ 1.0%	2	736.5	32.7	32.5
	3	725.7	32.3	
	1	727.3	32.3	
SFRC @ 1.5%	2	715.4	31.8	32.2
	3	734.5	32.6	
	1	815.1	36.2	
SFRC @ 2.0%	2	829.9	36.9	36.6
	3	826.7	36.7	

Source: Computed by the researcher from the laboratory results (2025)

Table 3.4: Compressive strength of cubes cured for 28 days.

Cube description	Sample Number	Ultimate load (KN)	Compressive strength (N/mm^2)	Average compressive strength (N/mm^2)
	1	543.5	24.2	
PC	2	592.1	26.3	25.4
	3	575.3	26.6	
	1	648.8	28.8	
SFRC @ 0.5%	2	602.9	26.8	28.2
	3	652.1	29.0	
	1	751.1	33.4	
SFRC @ 1.0%	2	732.2	32.5	33.2
	3	755.8	33.6	
	1	770.3	34.2	
SFRC @ 1.5%	2	755.8	33.6	34.0
	3	772.6	34.3	
	1	848.8	37.7	

SFRC @ 2.0%	2	859.3	38.2	38.1
	3	867.2	38.5	

Source: Computed by the researcher from the laboratory results (2025)

The results showed modest improvements in compressive strength with increasing fibre content. Maximum enhancement was observed at an optimum fibre dosage, after which further additions yielded negligible or reduced strength gains. Notably, 21-day results provided an intermediate performance trend that closely aligned with 28-day values, highlighting the progressive development of compressive strength.

3.3 Splitting Tensile Strength

Steel fibre addition had a pronounced effect on tensile performance.

Table 3.5: Split Tensile strength of samples cured for 7 days.

Cube description	Sample Number	Ultimate load (KN)	Compressive strength (N/mm^2)	Average compressive strength (N/mm^2)
	1	121.4	172	
PC	2	121.8	1.72	1.72
	3	122.0	1.73	
	1	124.9	1.77	
SFRC @ 0.5%	2	123.6	1.75	1.76
	3	124.4	1.76	
	1	153.4	2.17	
SFRC @ 1.0%	2	155.2	2.20	2.19
	3	154.8	2.19	
	1	166.4	2.35	
SFRC @ 1.5%	2	167.2	2.37	2.36
	3	166.8	2.36	
	1	200.4	2.83	
SFRC @ 2.0%	2	201.3	2.85	2.85
	3	202.0	2.86	

Source: Computed by the researcher from the laboratory results (2025)

Table 3.6: Split Tensile Strength of Cube cured for 14 days.

Cube description	Sample Number	Ultimate load (KN)	Compressive strength (N/mm^2)	Average compressive strength (N/mm^2)
	1	109.6	1.55	
PC	2	114.5	1.62	1.59
	3	113.8	1.61	
	1	122.3	1.73	
SFRC @ 0.5%	2	121.6	1.72	1.72
	3	121.6	1.72	
	1	145.0	2.60	
SFRC @ 1.0%	2	144.9	2.05	2.08
	3	145.0	2.10	
	1	159.0	2.25	
SFRC @ 1.5%	2	159.7	2.26	2.26
	3	160.5	2.27	
	1	192.3	2.72	
SFRC @ 2.0%	2	191.6	2.71	2.72
	3	192.3	2.72	

Source: Computed by the researcher from the laboratory results (2025)

Table 3.7: Split Tensile strength of samples cured for 21 days.

Cube description	Sample Number.	Ultimate load (KN)	Compressive strength (N/mm^2)	Average compressive strength (N/mm^2)
	1	124.1	1.76	
PC	2	123.9	1.75	1.76
	3	124.3	1.76	
	1	128.9	1.82	
SFRC @ 0.5%	2	129.0	1.82	1.82
	3	128.8	1.82	
	1	158.3	2.24	
SFRC @ 1.0%	2	157.9	2.23	2.23
	3	157.5	2.23	
	1	173.1	2.45	

SFRC @ 1.5%	2	172.4	2.44	2.44
	3	172.4	2.44	
	1	204.3	2.89	
SFRC @ 2.0%	2	208.4	2.95	2.93
	3	208.7	2.95	

Source: Computed by the researcher from the laboratory results (2025)

Table 3.8: Split Tensile strength of samples cured for 28 days.

Cube description	Sample Number	Ultimate load (KN)	Compressive strength (N/mm^2)	Average compressive strength (N/mm^2)
	1	126.4	1.72	
PC	2	127.1	1.80	1.72
	3	126.3	1.79	
	1	135.8	1.92	
SFRC @ 0.5%	2	135.5	1.92	1.92
	3	135.3	1.92	
	1	161.8	2.28	
SFRC @ 1.0%	2	159.8	2.26	2.27
	3	161.4	2.28	
	1	176.5	2.50	
SFRC @ 1.5%	2	179.3	2.51	2.51
	3	178.1	2.52	
	1	213.4	3.02	
SFRC @ 2.0%	2	212.9	3.01	3.02
	3	213.6	3.02	

Source: Computed by the researcher from the laboratory results (2025)

The inclusion of fibres significantly increased splitting tensile strength across all curing ages. The improvements were more consistent and substantial compared to compressive strength, demonstrating the effectiveness of steel fibres in enhancing crack resistance and post-cracking load capacity.

3.4 Durability Indicators and Load Behaviour

Durability-related properties and load-deformation responses further highlighted the benefits of fibre reinforcement.

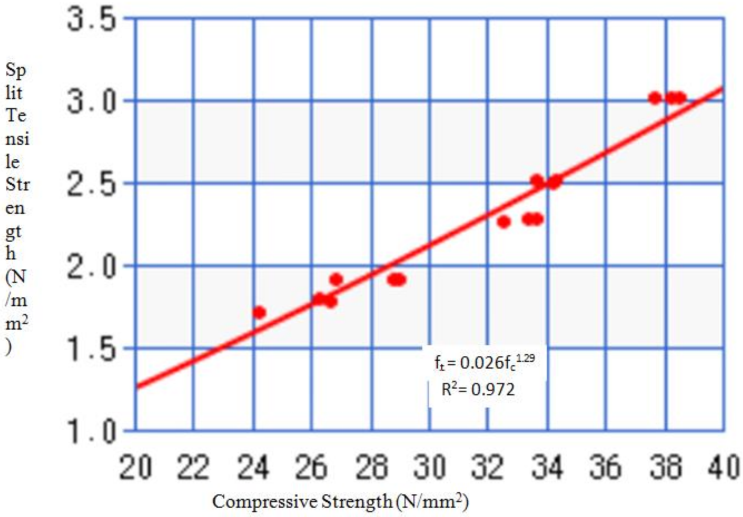

Figure 3: Correlation between compression and split tensile strength.

The results indicated that steel fibre reinforced concrete exhibited improved ductility, toughness, and energy absorption capacity. These properties are critical for structures subjected to dynamic or impact loads. The durability indices also confirmed that fibre inclusion reduces microcrack propagation, extending the service life of concrete structures.

3.5 DISCUSSION

The overall findings confirm that while compressive strength gains from steel fibres are moderate, tensile strength and durability characteristics improve significantly. The addition of 21-day test results provided a more detailed understanding of intermediate performance, bridging the gap between early and long-term strength development. This is attributed to the fibre bridging mechanism, which restrains crack widening and enhances post-cracking behaviour. Comparisons with previous research confirm the consistency of these outcomes, reinforcing the suitability of steel fibre reinforced concrete for applications requiring improved tensile performance and structural resilience.

3.6 Regression Modelling Between Compressive and Tensile Strength

Regression analysis established a strong power-type relationship between compressive and splitting tensile strength, expressed as: $f_t = 0.026 f_c^{[1.29]}$

This model indicates that tensile strength grows at a faster rate than compressive strength due to the fibre bridging effect. Experimental and predicted tensile strengths were closely aligned, demonstrating high reliability of the model. Table 3.9 presents the statistical parameters (RMSE and MAE) derived from error analysis.

Table 3.9: Results of error analysis from statistical parameters.

Source	Equations	Root Mean Square Error	Mean Absolute Error
Proposed Equation	$0.026f_c^{1.29}$	0.106	0.091
AC1 Committee (2014)	$0.56f_c^{0.5}$	0.887	0.855
CEB –FIB (1991)	$0.3f_c^{0.66}$	0.671	0.642
Corino & Lew (1982)	$0.272f_c^{0.71}$	0.885	0.870
Oluokun et al (1991)	$0.294f_c^{0.69}$	0.912	0.897
Arloglu et al (2006)	$0.387f_c^{0.63}$	1.131	1.119
Lavanya and Je'gan (2005)	$0.294f_t^{0.772}$	1.302	1.243

Source: Computed by the researcher from the laboratory results (2025)

The relatively low RMSE and MAE values confirmed that the model had strong predictive accuracy, validating its use as a tool for estimating splitting tensile strength from compressive strength results. This reduces the need for extensive tensile testing in practice and aligns with similar findings in literature that favour power-type models for concrete behaviour.

4. CONCLUSION

This study investigated the influence of steel fibre addition on the compressive and tensile strength behaviour of concrete. The findings revealed that:

i. The incorporation of steel fibres reduced workability but enhanced mechanical performance.

   Compressive strength showed modest improvements with increasing fibre dosage, with an optimum point beyond which further additions had diminishing effects. The 21-day curing results provided additional insight into progressive strength development.

ii. Splitting tensile strength exhibited significant and consistent gains across 7, 14, 21, and 28 days, highlighting the effectiveness of steel fibres in improving crack resistance and post-cracking behaviour.

iii. Durability indicators confirmed improved toughness, ductility, and energy absorption capacity, making SFRC suitable for dynamic and impact load conditions.

iv. Regression modelling produced a reliable power-type equation ($f_t = \underline{0.026}\ f_c^{\underline{1.29}}$)

v. Validated with RMSE and MAE, which enables prediction of tensile strength from compressive data with strong accuracy.

vi. The use of mould releasing agents during specimen casting ensured easy demoulding, preserved specimen geometry, and minimized surface defects, contributing to reliable testing outcomes.

Overall, the study concludes that steel fibre reinforced concrete offers considerable advantages for structural applications requiring enhanced tensile strength and durability.

It is recommended that future studies explore long-term durability performance under varied environmental conditions and the combined effects of steel fibres with other supplementary cementitious materials for sustainable construction.

REFERENCES

1. Elsa, A., & Ragat, K. Behaviour of steel fibre reinforced high strength self-compacting concrete beams under combined bending and torsion. *International Journal of Civil and Structural Engineering*, 2014; *4*(3): 315–331.
2. Grubl, A., Van, C., & Savoia, G. Post-cracking behaviour of steel macro-synthetic fibre-reinforced concretes. *Construction and Building Materials*, 2001; *25*(12): 2513–2521.
3. Hamid, B. Flexural behaviour of steel fibre reinforced concrete beams. *Journal of Materials in Civil Engineering*, 2010; *10*(2): 234–241.
4. Hannart, D. J. (2008). *Fibre cements and fibre concrete*. Chichester, UK: John Wiley & Sons.
5. Hisham, A. (2019, April 25). Mechanical effect of steel fibre on the cement replacement material of self-compacting concrete. *MDPI*. http://www.mdpi.com/...
6. Iqbal, S., Ali, A., Holschemacher, K., & Bier, T. A. Mechanical properties of steel fibre reinforced high strength lightweight self-compacting concrete. *Construction and Building Materials*, 2015; *98:* 325–333.
7. Jaber, A. Relationship between splitting tensile and compressive strength for self-compacting concrete containing nano- and micro-silica. *Journal of Building Engineering*, 2018; *162*(2): 1–10.
8. Jodeiri, A., & Quitalig, R. Effect of steel-fibre on flexural capacity of reinforced concrete beam. *Journal of Civil Engineering Research*, 2012; *2*(4): 100–107.

9. Johnson, A., & Zemp, D. Experimental behaviour of steel fibre high strength reinforced concrete and composite columns. *Journal of Constructional Steel Research*, 1991; *4*(2): 92–99.
10. Johnston, D. C. (1974). Properties of steel fibre reinforced mortar and concrete. In *International Symposium on Fibrous Concrete* (xx–xx). Lancaster, UK.
11. Johnston, D. C. Mechanical properties of steel fibre reinforced concrete. *Journal of Materials in Civil Engineering*, 1996; *9*(5): 384–389.
12. Johnston, D. C. (2001). *Fibre-reinforced cements and concretes*. Boca Raton, FL: CRC Press.
13. Khaloo, A. R., & Kim, N. Mechanical properties of normal to high-strength steel fibre-reinforced concrete. *Concrete and Aggregates Journal*, 2016; *18*(2): 92–97.
14. Khaloo, A., Raisi, E. M., Hosseini, P., & Tahsiri, H. Mechanical performance of self-compacting concrete reinforced with steel fibres. *International Journal of Innovative Research in Science, Engineering and Technology*, 2014; *3*(3): 231–242.
15. Knapton, G. Experimental investigation on structural performance of steel fibre reinforced concrete beam. *International Journal of Engineering and Advanced Technology*, 2003; *3*(6): 125–132.
16. Lavanga, G., & Jegan, J. Evaluation of relationship between split tensile strength and compressive strength for geopolymer concrete of varying guides and molarity. *International Journal of Applied Engineering Research*, 2015; *10*(15): 33523–33527.
17. Mahalingam, M., Pulipakka, R., Rao, N., & Kannam, S. Ductility behaviour of fibre reinforced concrete beams strengthened with externally bonded glass fibre reinforced polymer laminates. *American Journal of Applied Sciences*, 2013; *10*(1): 107–111.
18. Moretto, O. An investigation of the strength of welded stirrups in reinforced concrete beams. *ACI Materials Journal*, 2015; *42*(11): 141–162.
19. Morgan, D., & Mowat, D. A comparative evaluation of plain, mesh, and steel fibre reinforced concrete. *Journal of Materials Science*, 1984; *2*(4): 233–241.
20. Naaman, A. E., & Najim, H. Bond-slip mechanics of steel fibres in concrete beams. *ACI Materials Journal*, 2012; *8*(2): 135–145.
21. Naaman, A. E., & Reinhaudt, W. (2015). *Characterization of high performance fibre reinforced cement composite*. Ann Arbor, MI: Author.
22. Nataraja, M., & Nagaraj, T. Re-proportioning of steel fibre reinforced concrete mixes and their impact resistance. *Cement and Concrete Research*, 2005; *35*(12): 2350–2359.

23. Nawy, E. G. (2001). *Reinforced concrete: A fundamental approach*. New York, NY: Pearson Education.
24. Nawy, E. G. (2009). *Fundamentals of high-performance concrete*. New York, NY: John Wiley & Sons.
25. Noghabai, K. Beams of fibrous concrete in shear and bending: Experiment and model. *Journal of Structural Engineering*, 2010; *126*(2): 243–251.
26. Oluokun, F. A., Burdette, E. G., & Deatherage, J. H. Splitting tensile strength and compressive strength relationship at early ages. *ACI Materials Journal*, 1991; *88*(2): 115–121.
27. Raakrish, V., & Zellens, R. Performance characteristics and fatigue of polypropylene fibre reinforced concrete. *ACI Materials Journal*, 2017; *10*(8): 159–177.
28. Remakrishnan, V. Fibre reinforced concrete properties. *Materials and Structures*, 1985; *38*(5): 401–411.
29. Richant, B. (2015). An investigation of web stresses in reinforced concrete members. *Experiment Station Report*. Illinois, USA.
30. Richardson, A., Alberto, C., & Giovanmi, M. Fibre reinforced concrete: An overview after 30 years of development. *Cement and Concrete Composites*, 2010; *18*(3): 104–124.
31. Roesler, J. Effects of synthetic fibre on structural behaviour of concrete slab-on-ground. *ACI Materials Journal*, 2003; *104*(2): 3–10.